

Forestry Commission

**REPORT ON
FOREST RESEARCH
1982**

Forestry Commission
ARCHIVE

REPORT ON
FOREST RESEARCH

for the year ended
March 1982

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The abbreviated title of this Report is:
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Front Cover: Work on the use of clear plastic “tree shelters”, now in its fourth year, is highly promising. Growth of young oak is very considerable, survival is increased, protection is offered against rabbits and deer, and weed control is made easier and safer. (*D. A. Burdekin*).

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INTRODUCTION

By A. J. GRAYSON

Director of Research and Development

House of Lords Committee

The Government's response to the Report of the House of Lords Select Committee on Science and Technology, which investigated scientific aspects of forestry in Britain, was announced in February 1982. The Government largely accepted the findings of the Select Committee in relation to forestry research and agreed that the Forestry Commission should assume responsibility for co-ordinating the broad strategy of forestry research in Britain. A Forestry Research Co-ordination Committee is to be set up to act as a forum to identify research requirements and opportunities and to encourage the co-ordination of research programmes in forestry. This Committee will be under the chairmanship of the full-time Forestry Commissioner responsible for research and will include the Commission's Director of Research and senior representatives of the Natural Environment Research Council, the Agricultural Research Council, the Commission's Research Advisory Committee, the Department of the Environment, the Nature Conservancy Council and Agriculture Departments.

The Government response stated that careful consideration had been given to the Select Committee's associated recommendation that the Commission should appoint a Chief Scientist to carry out its wider co-ordination responsibility, and through him stimulate and commission research which would complement and support its own research programme. The co-ordination role would be fulfilled by the new Committee. In relation to the commissioning of research with outside bodies, it was accepted that, within the financial resources available, it was desirable to maintain an appropriate balance within the Forestry Commission's research expenditure between applied and strategic research. The Forestry Research Co-ordination Committee would keep this balance under review but in the present period of economic stringency no additional funds could be provided for the Commission's research budget. Against this background, the Government concluded that the appointment of a Chief Scientist could not in present circumstances be justified.

Several fields of importance in relation to the content of forestry research are covered in the Government response. Among those that may be noted are that, while more effort should be applied to work on wood properties, the Government considered that responsibility for wood research should not be transferred from the Princes Risborough Laboratory of the Building Research Establishment to the Forestry Commission; that the Forestry Commission would continue to work closely with the NERC Institute of Hydrology on the interactions between forestry and water resources and with the NERC Institute of Terrestrial Ecology in studies of long term effects of trees on soil fertility and other environmental factors; and that in relation to the recommendation of the Select Committee favouring the diversification of forests in both age and composition, it was noted that some reduction in reliance on a relatively small range of species would be prudent. The Committee made a number of recommendations on the subject of integrated land use. In this regard the Government agreed that this was an important subject but one "on which it is extremely difficult to design critical research".

Seed Supply

Responsibility for seed extraction and buying and selling seed in the Forestry Commission was transferred to Forest Management Division in Edinburgh at the end of the year under report. The seed extractory and seed store continue to be sited at Alice Holt Lodge; seed testing and seed research will still be undertaken by the Research Division.

Vegetative Propagation

Further refinements have been made to the system for propagation of Sitka spruce developed at the Northern Research Station and a trial approaching field conditions has been started in a polythene house at Newton Nursery (Grampian Region). Difficulties with poor rooting and plagiotropism in Hybrid larch cuttings remain to be overcome. Encouraging results were obtained with rooting of softwood cuttings for a number of broadleaved species.

Motorway Planting

The importance of maintaining newly planted trees free from weed competition has been confirmed by more detailed assessments in experiments established under the Department of the Environment's arboriculture contract. Black polythene "mulches" have been shown to have highly beneficial effects on trees planted on a very dry site.

The Cold Winter of 1981/82

Extremely low temperatures were experienced throughout Britain in December 1981, the coldest December for a century, and in mid-January 1982 when the most severe weather occurred. At Alice Holt an air minimum temperature of -12.4°C was recorded on 14 January compared with a 10 years mean of daily minima for January of $+0.7^{\circ}\text{C}$. All-time lows were recorded at Shawbury in Shropshire (-25.2°C , compared with the previous record for England of -23.3°C observed 101 years before) and at Braemar (Grampian Region) with -27.2°C . Such extreme temperatures provide a rare and stringent test of the less familiar genera of *Eucalyptus* and *Nothofagus*.

Root Studies

Valuable understanding is being gained of the architecture and structural performance of root systems of Sitka spruce. The investigation of root rupture when a tree is pulled over has been aided by the use of buried microphones which record the sound of breaks.

Birds

In the course of studies of raptors in areas influenced by afforestation, the habitat requirements of tawny owl and goshawk in upland spruce forests are being defined.

Biological Control – Pheromones

An active programme of tests, including analyses of pheromone dispersal away from point sources, is being pursued in association with the Chemical Entomology Unit of Southampton University.

Oak Wilt

Pathology Branch have devised a technique for the detection of roots grafts in European oak, an important means of transmission of oak wilt, under a joint EEC/USA study on this wilt disease. In addition, Dr J. N. Gibbs, with a French colleague, Dr J. Pinon, visited the USA in September to investigate the progress of work on treatment designed to eliminate the risk of the disease reaching Europe on oak logs or sawnwood. Arrangements were also made for the establishment of trials in West Virginia and South Carolina in which European oaks can be tested for resistance to the disease. In March, Dr Gibbs organised an "EEC Oak Wilt Co-ordination Meeting" in Belgium, at which it was accepted that fumigation with methyl bromide could provide a satisfactory treatment for North American oak logs and sawnwood.

Beech Bark Disease

We are grateful to the Stanley Smith Horticultural Trust and to the Thomas Phillips Price Trust for grants which enabled Dr D. Lonsdale to continue his research on beech bark disease until November, an additional 3 years beyond his original period appointment at Alice Holt Lodge.

Census of Woodlands and Trees

The field work of this major Census was close to completion at the year's end and the complex programs required to provide population estimates of such features as area, number, size-class and health-class have been successfully run on the sample data from a number of counties.

Production Forecasts

The third regular quinquennial revision of growing stock description and runs of the production forecasting program for all Commission forests have been completed. This round has seen the application of a wider range of thinning models than ever before.

Tree Planting by the Prince of Wales

His Royal Highness the Prince of Wales visited Westonbirt Arboretum on 5 March 1982 to plant trees to mark his wedding to the Lady Diana Spencer and to commemorate the Diamond Jubilee of the Commonwealth Forestry Association of which Her Majesty the Queen is Patron.

Retirement of D. R. Johnston

Mr D. R. Johnston, Director of Research and Development since 1973, who organised the merger of the former Research Division with Field Surveys and Work Study Branches, retired at the end of the year.

Forest Researchers from Overseas

Mr. J. L. Shi, a visiting scientist from the People's Republic of China, started work which will explore the possibility of using bacteria for the control of Dutch elm disease. In connection with studies of windthrow, Mr A. J. G. Papesch of the University of Canterbury, New Zealand has returned to the Northern Research Station under a grant provided by the Forestry Commission to undertake studies of wind-flow through plantations.

Visitors

A total of 4,500 people, including 1,200 invited guests on one day, visited Alice Holt during Open Days in July 1981. Other visits by parties and individuals to Alice Holt Lodge totalled 540 people and to the Northern Research Station 385. The Division was responsible for the Forestry Commission exhibit at the Chelsea Flower Show.

Visits and Conferences

The Director, Mr. D. R. Johnston, assisted in the organisation of the XVIth Congress of the International Union of Forest Research Organisations in Japan. The Director designate Mr. A. J. Grayson and Dr M. P. Coutts joined him at Kyoto to participate in the Conference. Other visits abroad totalled 23 and participation in conferences and symposia in the United Kingdom amounted to 55.

Staff

At year end the Division employed 318 non-industrial staff and 155 industrial grade staff. Names of Forester, Forest Officer and Scientific staff are listed by Branch in Appendix III.

PART I

The Work of the Forestry Commission

RESEARCH AND DEVELOPMENT DIVISION

SEED

Research

Laboratory Experiments

The main areas of research have been the pretreatment of broadleaved seed affected by dormancy problems and the improvement of 'quick' methods for determining the viability of such seed. The heavy beech mast of 1980 provided ten seed lots of *Fagus sylvatica* for use in this investigation. A biochemical test using tetrazolium is the main method of assessing the viability of beechnuts but it has often been criticised on the grounds of over-estimating the germination value. This effect is due in part to subsequent seed deterioration during the long pretreatment necessary before germination occurs.

In the past tetrazolium has been used as a one per cent solution with a topographical assessment as prescribed by the International Seed Testing Association (ISTA) Rules for Testing Seed. However, many seed analysts have been concerned with improving the method. At an ISTA Workshop held in Norway in June 1981, tetrazolium solutions down to 0.1 per cent were advocated, together with methods requiring increased attention to the condition of the tissues by dissection and microscopical examination. Unfortunately this means fewer seed can be tested in the time available and analysts would require more specialized training.

A 0.5 per cent solution gives adequate staining for the determination of living tissue. Initial tests on receipt of beech seed were found to give a good correlation with the germination obtained later in the spring for six of the ten lots. One gave an underestimate of germination by 30 per cent, and three gave an overestimate by between 26 and 45 per cent on a germinable seed basis. These results may be considered satisfactory when possible deterioration is considered, and were confirmed by subsequent retesting with tetrazolium at the time of sowing. It was shown that high germination values, and a germination survival factor of 80 per cent, could be obtained in the nursery by autumn or spring sowing, although normal nursery practice would allow for not more than 50 per cent survival.

Nursery Experiments

The germination of three conifer species was compared for different seed covering materials with and without 50 per cent shade. The influence of temperature at the germination level beneath the covering material was studied in detail. Thermistors indicated that in direct sunshine yellow brown grit and yellow brown sand were about 3°C and 1°C warmer than white sand, respectively. The temperatures in direct sunshine of unshaded plots were generally 9°C higher than those of shaded. Under other weather conditions these differences were reduced.

Influences on both rates of germination and maximum percentage germinations were recorded. Higher germination was obtained without shade for Lodgepole pine and Sitka spruce but Western hemlock germination was higher when shaded. Yellow brown grit appeared preferable for Lodgepole pine and Sitka spruce without shade, but the effect of covering material on Western hemlock was negligible. The germination of unchilled seed for all species was more adversely affected by covering and shading than chilled seed. Some shaded unchilled seeds were so retarded that they were still germinating in August.

When the shading was removed at the end of August, little difference could be seen between height of shaded or non-shaded conifers. However, by December Lodgepole pine and Sitka spruce were 70 per cent taller and Western hemlock was 17 per cent taller in non-shaded treatments. It was apparent that the seedlings from which the shade had been removed lacked the potential for growth in the late growing season.

Service

Official Seed Testing Station

The operation of this unit occupied approximately two-thirds of the staff time. In the course of the year nearly 3,000 tests were performed on almost 600 samples. The majority of these were on new and stored seed lots for the Forestry Commission. Private samples fell from five per cent to one per cent of the total number of tests.

During the summer it was suspected that optimum germination was not being achieved on the Copenhagen Tanks, but the reason for this was not readily identifiable owing to the absence of any visible cause such as mould. Samples of water sent to the Commonwealth Mycological Institute revealed the presence of several species of bacteria, and it was suggested that one of these might be capable of opportunist pathogenicity. The germination room was closed for the first time in 22 years, the equipment dismantled and the room completely sterilised with Stericol (2 per cent phenol). This treatment was entirely successful and subsequent repeat tests of affected seed lots have shown that germination in some instances had been reduced by up to 63 per cent. During the sterilisation procedure, modifications were made to the germination equipment to increase reliability and reduce the likelihood of further infections.

D.C. WAKEMAN

SILVICULTURE (SOUTH)

Plant Production

Bare Rooted Broadleaved Trees Grown in an Unheated Polythene Greenhouse

In a small pilot trial of three broadleaved species, beech, Red oak and sycamore, height growth was much increased but percentage survival considerably reduced inside the unheated polythene greenhouse compared with similar stock grown in the open.

J.S.P. SALE, P. HOWARD

Vegetative Propagation

Much of the effort was again centred on devising cost-effective techniques for reproducing broadleaved trees from softwood cuttings. The influence of age of stock plant, substrate temperature, hormone treatment and overhead and side shade on root initiation and development received special attention. Several encouraging results were obtained. In particular, exceptionally successful rooting (95 to 100 per cent) was achieved with *Ulmus* 'Dodoens' (*U. glabra* x *wallichiana*), Common ash, sycamore and London plane on unheated benches equipped with automatic overhead mist irrigation. Cuttings of the last three achieved 100 per cent rooting without any hormone treatment before insertion. These high takes were obtained with cuttings taken from young stock plants in late June and early July. Some progress was made in propagating selected oak clones.

J. JOBLING, P. MARSH

Lowland Silviculture

Broadleaves – Silviculture

Several derelict woodland rehabilitation experiments laid down in the 1950s have been re-assessed. The least costly option of enriching gaps and favouring existing stems of utilisable potential will produce a reasonable crop on many sites, provided release cleanings and thinning are carried out every few years.

More extensive foliar sampling of oak woodland around Dartmoor (*Report* 1981, p.14) has generally confirmed low phosphate levels in leaves. Ground survey has indicated that many stands are growing better than is generally believed and most are of Yield Class 4 or 6. Experiments are being laid down to compare alternative management regimes within the constraint of retaining broadleaved woodland.

Investigations into control of epicormics on oak are continuing (*Report* 1981, p.14). A re-assessment of an oak provenance trial and an extensive survey of 30–40 year old oak plantations confirm that: a) Sessile oak is less prone than Pedunculate oak to develop epicormics; b) within any stand, dominant trees have fewer epicormics than those in other crown classes.

J. EVANS, K. F. BAKER, R. E. PRESTON, R. E. WARN

Eucalyptus

Five large trials and four small ones have been laid down on a wide range of sites throughout Britain with the object of determining systematically whether any eucalypt is sufficiently hardy to have a forest potential. One hundred and two seed origins of 15 potentially hardy species are being tested.

The exceptional winter of 1981/82 provided a thorough test at the end of the first growing season. On the coldest sites, where temperatures fell below -19°C (Chiddingfold, Thetford and Wark), all trees of most seed origins were killed back to ground level, but significant above-ground survival has been shown by *E. pauciflora* ssp. *debeuzevillei* and ssp. *niphophila*. Also, many trees with dead tops, of both these and some other species, have begun sprouting from the base.

J. EVANS

Tree Shelters

In their third year Sessile oak transplants continued to grow better when protected by shelters (Front Cover).

TABLE 1

GROWTH OVER 3 YEARS OF OAK IN SHELTERS COMPARED WITH TREES WITH TREEGUARDS* AND CONTROLS (UNPROTECTED)

Treatment	Height (cm)				Diameter (mm) at 5 cm height				Ratio of Increment over 3 years	
	At plant- ing	End of 1979	End of 1980	End of 1981	At plant- ing	End of 1979	End of 1980	End of 1981	Height	Diameter
Control	22	22	34	42	4.1	5.0	5.4	8.5	0.4	0.7
Treeguard*	22	26	53	71	4.1	5.3	6.4	10.6	1.0	1.0
Shelters†	22	36	121	163	4.1	5.7	8.2	12.9	2.9	1.4

Notes: * Trade name for an individual tree guard made of polypropylene mesh.

† After three years' growth there was no significant difference between the four different designs of shelter used.

The "ratio of increment" compares the control and shelter treatments with the Treeguard which is commonly used to protect broadleaves planted at wide spacing. Oak in shelters has more taper in the bottom 0.3 m of stem than between 0.3 m and the top of the shelter at 1.2 m. Above the shelter there is rapid taper similar to that in the other treatments.

On five sites scattered through southern Britain, beech, sycamore, birch, Common alder, Field maple and hawthorn grew more than twice as much in height after two years in shelters as in Treeguards. The response of *Nothofagus procera* has been variable. Seven conifers on these sites grew better in shelters but not as well as the broadleaves. There is some evidence that tree shelters deter roe deer, but cows knock them over and eat the shoots; there have been a few cases of damage by humans.

The technique of using shelters with broadleaves has been recommended for large-scale trial and 100,000 will be used in the 1981/82 planting season. Shelters manufactured from corrugated polypropylene are currently considered the most suitable, but research into alternative materials continues.

G. TULEY, P. RISBY

Nothofagus

Winter damage to *Nothofagus* nursery stock was more severe in 1981/82 than in 1978/79. It will be June 1982 before the damage to different seed origins which were planted in 1978 and 1979 can be determined.

Fast Growing Pines

Bishop pine (*Pinus muricata*) and Monterey pine (*P. radiata*) nursery stock was protected by snow during the severe weather in 1981/82 and suffered less damage than in the 1978/79 winter.

G. TULEY, P. HOWARD

Forest Weed Control

An unreplicated trial of fosamine ammonium applied to broadleaved scrub indicated that adequate initial control of most of the species present was achieved at 10 litres of product (4.8 kg a.i.) per hectare, and that mistblower application at low volume (100 litres per hectare) was more effective than medium volume (250 litres per hectare) applied through a knapsack sprayer.

When cyprazine was applied at medium volume (300 litres per hectare) to heather on four different dates, the greatest control was achieved by the late June and July applications. The late August treatment was disappointing when assessed in October but may show some effect in the following season. With the addition of Actipron there was no improvement in heather control, and the health of the Corsican pine crop showed some deterioration. There was very little difference between the effects of the two dose rates applied (3 and 4 kg a.i. per hectare).

Among transplants of six conifer species treated with asulam, those treated with sprays containing the additive Dessipron showed poorer health at the end of the first season than those sprayed with asulam alone.

Glyphosate, solubilised glyphosate, fosamine and triclopyr ester were tested in March as cut-stump treatments on poplar stools at two concentrations, using 2, 4, 5-T as a comparative treatment. Only triclopyr (at both levels) performed as well as the 2, 4, 5-T. The higher concentrations of fosamine and solubilised glyphosate achieved adequate control. The plain glyphosate was the least effective treatment.

J. S. P. SALE, D. ELGY, P. RISBY, C. SHANKS

Arboriculture – Department of the Environment Contracts

Motorway Planting

A linear relationship was found between radius of weed controlled area and height and basal area increment of Italian alder, sycamore and hawthorn transplants in a trial at Ripley, Derbyshire. Trees surrounded by a weed free area of 0.5 metres radius grew approximately twice as much during the first 3 years after planting as trees in control plots with no weeding. Using both greenhouse and other field experiments (*Report* 1981, pp.15–16) this response has been related to competition by grass for water and nutrients. A series of new experiments has now been established to examine variation in this response with rainfall and summer soil moisture deficit. The interaction between weed control and the use of tree shelters (*Report* 1981, p.12) will also be investigated.

Black polythene mulches have been found to produce dramatic improvements in survival and growth of Italian alder transplants and Crack willow cuttings on a very dry site at the Portsmouth Harbour M275 Interchange, where previous plantings had repeatedly failed and where rigorous weed control was not enough to overcome the seasonal drought problem.

Production of Amenity Stock

A trial, carried out in conjunction with Hillier Nurseries (Winchester) Ltd., to test the effect of undercutting ash, sycamore and Box elder (*Acer negundo*) standards one year before lifting has shown that root:shoot ratio and root morphology were altered. However, the difference was largely lost because of

severe root pruning during lifting, and ultimately there was no difference in survival or growth when trees were planted out.

H. INSLEY, J.B.H. GARDINER

Arboriculture Advisory and Information Service

The Service received 1,622 requests from local authorities, professional people, the media and public. The scope of the enquiries tended to reflect the seasons. Diseases such as willow anthracnose featured during the spring and summer with the emphasis in the dormant season being on Christmas tree growing. Latterly there was increasing concern about the effects of the unusually cold weather on evergreen trees and shrubs.

Dissemination of technical information continued with the publication of seven new titles in the Arboriculture Research Note series. In addition four earlier Notes were updated. The new titles were:

34. Selection of species for planting over domestic refuse.
35. Tree roots and underground pipes.
36. Winter shelter for agricultural stock.
37. Reclamation of surface workings for trees –I: Landforms and cultivation.
38. Reclamation of surface workings for trees –II: Nitrogen nutrition.
39. Coryneum canker of Monterey cypress.
40. Tree staking.

D. PATCH, F.R.W. STEVENS

Colliery Spoil

In experiments started in 1979 and 1980 to study early tree behaviour in compacted spoil, assessments again revealed that survival and growth rates in the first two to three seasons may be appreciably improved by planting in recently cultivated spoil. No evidence was obtained to suggest that either vigour or mortality of young trees are influenced by intensity of cultivation. Further observations are required to see if trees can be properly established in spoil cultivated only at the planting position by a soil crumbler. Experiments set up in 1981 to examine the relationship, if any, between early tree behaviour and type, quality and size of tree and season of planting may have to be observed for a further growing season before clear conclusions can be reached. The work is being carried out primarily in Northumberland, Durham and West Yorkshire.

J. JOBLING

Short Rotation Coppice – Department of Energy Contract

The establishment of experiments designed to determine optimum spacing and rotation is now complete. This project is now funded jointly by the Department of Energy and the European Economic Community. A desk study by forestry and agricultural contractors on land availability for wood energy plantations taking into account technical, social and economic factors is about to be completed.

M.L. PEARCE

Dendrology and Arboreta

Dendrology

Some trees on 67 estates were remeasured and those of 55 estates were measured for the first time. Three thousand five hundred and eighty-one specimens were added to the register bringing the total to 58,179 (34,278 conifers; 23,901 broadleaved trees) of 1,445 species and 867 varieties. Five thousand nine hundred and twenty-five specimens were measured altogether. A particular survey was made of the oldest and biggest trees of *Metasequoia* in Britain and, for comparison, in the eastern USA, and published in 'The Garden'. The Giant Sequoia (*Sequoiadendron giganteum*) increased its lead over all other species with 1,775 specimens.

Bedgebury National Pinetum

A substantial concrete footbridge over the stream, inconveniently placed for the new path system, was removed by high explosive and the banks there and elsewhere made good and planted with shrubs to limit access for safety reasons. The season was not a good one for flowering and little seed was collected, but growth was good in most species.

A.F. MITCHELL

Westonbirt, Gloucestershire

Spring snowstorms severely damaged some 1,000 specimen trees, particularly members of the *Rosaceae*. The John White Willow Collection now has over 230 species and cultivars, including new material from Canada, Spitzbergen and Switzerland. Information for visitors has been improved by establishing two trails: a two mile 21 stop route through Silk Wood with an illustrated guide, and a shorter autumn colour trail through Acer Glade. His Royal Highness the Prince of Wales visited the arboretum on 5 March 1982 and planted an Oregon ash (*Fraxinus latifolia*) to commemorate his wedding and a Red maple (*Acer rubrum*) to mark the Diamond Jubilee of the Commonwealth Forestry Association.

M.L. PEARCE

SILVICULTURE (NORTH)

Production of Planting Stock

Vegetative Propagation

Rooted cuttings produced for large-scale afforestation must come from young material if the costs of production are to be kept low. Cuttings from older material give a lower percentage rooting and have a poorer root system. The number of rooted cuttings that can be produced from young stock plants will determine the productivity of a limited supply of genetically improved material. Seed of proven genetic quality were grown to give stock plants at two years old of 80–100 cm height.

Experiments at Bush Nursery (Lothian) to find the optimum size of cuttings compared percentage rooting and root score. Cuttings ranged in

length from 10 cm down to 4 cm and were of varying thickness. Tips of shoots were compared with basal portions of shoots.

For Hybrid larch inserted in July the basal portions of shoots gave poor rooting (27 per cent). Shorter cuttings were not as good as longer ones but the rooting achieved even with 4 cm tip cuttings (52 per cent) was good. The thickness of the cutting had more effect, with very thin cuttings giving poor performance.

Sitka spruce inserted in March showed a similar pattern, but both the percentage of rooting and root scores were much better than for larch. Basal portions of shoots gave 69 per cent rooting as compared with 84 per cent for the tips. Length of cutting made little difference to rooting success until it dropped below 6 cm. Little difference in rooting ability was found between cuttings of various thicknesses.

In other experiments on vegetative propagation of cuttings a good correlation was found when the percentage rooting and root score of clones taken from 10-year-old Sitka spruce in two different years were compared. In another experiment cuttings from 10-year-old plants of different provenances showed a cline in rootability correlated with the latitude of provenance with the more northerly provenances having poorer roots.

P. BIGGIN

Plant Handling

The development of water stress during handling, and the relationship between plant moisture status at planting and subsequent survival, are being evaluated in a field experiment at Falstone Forest (Northumberland). Fieldwork follows preliminary laboratory work with a 'pressure bomb', an instrument which measures water potential.

P. TABBUSH

Planting

Deer Fencing

Following the result at Drummond Hill Forest (Tayside) (*Report* 1981, p.19) a further experiment has been laid down at Kershope Forest (Cumbria) designed to evaluate the economic benefits of fencing against roe deer and the interaction of weed control, browsing prevention and height growth of young trees on a weedy surface water gley soil.

Restocking

Despite a standard dipping treatment in gamma HCH, the experiment at Glenurquhart Forest (Highland) was attacked by *Hylobius abietis*. Significantly less damage occurred in plots which were either ploughed or scarified (no difference between these) than in uncultivated plots. *Hylobius* showed a marked preference for Douglas fir (71 per cent of trees damaged) over Sitka spruce (35.6 per cent of trees damaged). Nearly 100 per cent of the trees of both species survived after one growing season regardless of plant size, weevil damage, or cultivation treatment.

P. TABBUSH

Spacing

Mutual shelter in a four-year-old plantation has been shown to vary with stocking density. In a spacing experiment with Sitka spruce at Arecleoch Forest (Dumfries and Galloway) with treatments ranging from 1,111 to 3,086 stems per hectare, the level of exposure as measured by tatter flags over a period of three years was 8 cm² per day, thus placing the experiment in wind zone 3. The reduction in tatter rate from the lowest to the highest stocking density was of the order of 40 per cent when the trees had a mean height of about 1 m (tatter flag height was 1.3 m) but this was not reflected by any difference in height growth between stocking densities.

P. BIGGIN

Species

Seed Origin Experiments

Most of the results from the sixth year height assessment of the IUFRO series of 18 experiments with Sitka spruce have now been analysed individually. They show a broad genotype x environment interaction, with the southern origins growing better on southern sites and northern origins growing better on northern sites. This interaction is being further examined by an analysis of data pooled from all sites. This stage has also been reached with the larger series of experiments in which Lodgepole pine planted in 1969–1970 was assessed at ten years of age.

Experiments sown in 1981 gave good germination of *Abies amabilis* from a wide range of origins, though all grew slowly. Characteristically the seedlings set terminal buds quite early and produced a single side branch. They suffered little damage from the severe winter.

Germination was very variable in 30 seed lots of *Picea glauca*/*Picea engelmannii* sown in 1981 and seedling height also varied widely. The tallest (5.0 – 5.5 cm) came from the Skeena River area in north British Columbia, the south interior of British Columbia and Clackamas County, Oregon. Those from high elevations in the Rocky Mountains from Alberta to Colorado grew poorly, several growing less than 1 cm.

Twenty-eight *Alnus* species and seed origins were sown at Benmore, Strathclyde. This collection includes *Alnus rubra* from elevations up to 1,200 m on Vancouver Island, British Columbia, and 1,000 m in the Washington Cascade Mountains. The Asiatic species, *A. firma* and *A. nitida* germinated well but were then killed by autumn frosts.

Mixture Experiments

The joint Forestry Commission/Institute of Terrestrial Ecology experiment planted in 1955 at Gisburn (Bowland Forest) contains four species: Norway spruce, Scots pine, Sessile oak and Common alder, each pure and in mixture with each of the others. In the mixed plots the pattern of planting was a chequer board with units of 3 by 6 plants of each species. This arrangement would tend to be less effective in early “nursing” than an intimate mixture, but gives greater opportunity for maintaining a mixture if one species grows faster than the other.

The original objectives were to study differences in forest productivity and soil changes. The most valuable results are likely to come from studies of

long-term soil changes. Microbiological effects were already evident after 20 years (Brown, 1977).

The experiment was assessed for height growth at 26 years of age. Large differences in height occurred between species (Table 2 compares 10 year and 26 year heights). Comparison at both 10 and 26 years of the heights attained in mixtures with other species compared with that in pure plots showed that Scots pine has consistently the greatest "nursing" effect.

TABLE 2
DOMINANT HEIGHTS AND NURSING EFFECTS:
EXPERIMENT GISBURN 1 P.55 ASSESSED AT 10 AND 26 YEARS

10 Years	Height (m) of 'Nurse' Species in Pure Plots			
	NS	SP	Oak	C. Ald.
	1.83	3.23	2.01	2.44
'Nursed' Species	'Nursing' Effect (m) in Mixed Plots			
Norway spruce	-	+0.34	-0.34	-0.12
Scots pine	+0.25	-	+0.34	+0.13
Oak	-0.30	+0.49	-	-0.15
Common alder	-0.18	+0.12	-0.12	-
26 Years	Height (m) of 'Nurse' Species in Pure Plots			
	NS	SP	Oak	C. Ald.
	8.80	11.12	6.58	8.24
'Nursed' Species	'Nursing' Effect (m) in Mixed Plots			
Norway spruce	-	+1.82	-0.04	+1.04
Scots pine	+0.42	-	+0.22	0.0
Oak	-0.91	+2.24	-	+0.71
Common alder	-0.67	+1.07	-0.52	-

Regeneration Species Trials

A stand of poor 1920's Scots pine on windblown sands at Tentsmuir Forest, Fife, has been successfully replaced by Sitka spruce in an experiment incorporating strip felling where the soil water table was within 45 cm of the surface. Lodgepole pine of Skeena origin was the best species on the sites with a lower water table, but was used only on clearfelled plots. Grand fir was the only other species included in this experiment (Tentsmuir 7 P.72) and, being a shade bearer, was tallest in the underplanting treatments.

R. LINES

Cultivation

Effects of Site Preparation on Root Development and Stand Stability

Preliminary investigations using vertical tree-pulling techniques in site cultivation experiments were carried out in early thicket-stage Sitka spruce. Using these techniques the stability of such trees can be predicted and data gained on the static forces required to uproot trees, and on the root architecture of lifted trees, albeit early in the rotation. Results to date show

that clear and consistent differences in juvenile stability occur between site preparation treatments.

A series of extensive, first rotation, cultivation experiments has been established at Moffat Forest (Borders) on 12 ha of the Hallowburn Research Reserve. These experiments are primarily designed to investigate growth, root development and physical stability of Sitka spruce on a uniform peaty ironpan soil, comparing 12 different site preparations.

K. F. MILLER

Nutrition

Establishment Phase

Work continues towards determining the optimum fertiliser inputs for Sitka spruce and Lodgepole pine on the major upland soil types. Nitrogen deficiency continues to be a problem in the establishment of Sitka spruce on heathland mineral soils and unflushed peats, and experiments laid down on such sites in 1974 are now coming to fruition. It is clear that heather control alone will not permanently cure nitrogen deficiency on these sites and application of nitrogen fertiliser will often be required. The current recommended rate of application of 150 kg of nitrogen per hectare has been confirmed as the optimum rate, and comparisons between urea and ammonium nitrate as sources of nitrogen have shown no significant difference. The response to a nitrogen application can be expected to persist for three to four years, and time of year of application appears to have little effect on the magnitude or duration of the response.

Attention is also being focused on other means of enhancing the nitrogen status of Sitka spruce in the all important pre-canopy closure stage, for example by introducing a nitrogen fixing plant (tree lupin *Lupinus arboreus*) into newly planted Sitka stands. Investigations are continuing into the promising role of species mixtures in this field.

R. McINTOSH.

Forest Weed Control

Grass

The experiments in the 'need-to-weed' series are beginning to yield results. At Ae Forest (Dumfries and Galloway) and Brycheiniog Forest (Powys) there was a marked response in survival and growth of Sitka spruce plants following chemical weeding, the trees having been planted onto an already grassy site. At Brycheiniog and at Tummel Forest (Tayside) where trees had been planted on a clear site that subsequently became grassy there was little or no response to weed control, expressed either by survival or early growth.

Experiments comparing various herbicides applied in spring and summer showed glyphosate to give the most effective control of grasses. However it also caused some damage to Sitka spruce. To avoid such damage, glyphosate has to be applied late in the growing season, by which time the grass vegetation has developed fully and may already be interfering with tree growth.

P. TABBUSH, P. BIGGIN

Wind

Effects of Canopy Architecture on Wind Structure

Surface roughness strongly influences wind passing over a surface. Changes in surface roughness in forests produced by different spacing and thinning practices are likely to affect the turbulence of winds, with consequent changes in the effect of the wind on the trees. Early research at Redesdale Forest (Northumberland) between 1966–1972 detected changes in wind structure at the transition between open hill terrain, unthinned spruce plantation and thinned sections within the forest. Unfortunately, instrument sensitivity in this study was too low to define the more critical adjustments to wind conditions under these three surface roughness conditions.

A new project has been established to analyse interactions between wind conditions and stand architecture. Field experiments at Moffat Forest (Dumfries and Galloway) have been set up to record detailed wind structure changes at a series of heights of up to 23 m above a pole-stage Sitka spruce plantation. Three dimensional turbulence conditions are detected using five high sensitivity orthogonal arrays of Gill UVW anemometers. This information is recorded simultaneously with tree response data derived from accelerometer sensors attached to selected trees adjacent to the wind sensing equipment. At present the study area is unthinned, although it is intended to change the canopy roughness progressively by a series of thinnings. Observations will then be made of changes in the wind conditions above the stand and the dynamic response of trees within the plantation.

This field study is supported by scale-model investigations in the Boundary Layer Wind-tunnel at Oxford University, where simulated thinning and spacing arrangements will be incorporated into model forests. Consequent changes in the boundary layer wind profile and of tree deflections will be sensed and recorded using hot wire anemometry and cine film analysis respectively.

K.F. MILLER

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SITE STUDIES (SOUTH)

Foliar Analysis

Service

Eight thousand five hundred samples were presented for analysis; 450 were from conservancies and private growers and the rest from research projects. Development of data collection and handling facilities is continuing.

Methods

The gas chromatograph is used to study terpenes and polyphenolic compounds in plant tissues. Paper chromatography is being used to detect flavanoid compounds, and their associated glycosides, extracted from the bark of *Fagus* species in order to test if there is any connection between these compounds and attack by *Cryptococcus fagisuga*.

A phase-locked amplifier has been fitted to the Spectraspan III Emission Spectrometer. This permits the instrument to be used with precision much closer to the detection limit than was previously possible. Applications include the determination of trace elements (<10 ppm) in plant material digests rather than by use of the classical dry ashing technique. This greatly reduces operator time and produces more reliable results.

A new microwave plasma source is being developed which will be used to measure sulphur, chlorine and other elements which are difficult to quantify in plant and other materials. A Beenakker T₀₁₀ cavity, whose power is supplied from an EMS Microtron Mk II, produces a helium plasma which permits the observation of emission lines from these elements. The emission lines are not normally produced in an argon plasma.

Soil Analysis

Chemical transformations of soil phosphate have been studied by investigating the rate of uptake of orthophosphate from solution. The rate, at constant temperature, was dependent upon the geological origin of the soil and particle size distribution therein. There was no relationship with soil type. The rates of reaction were very much faster than for agricultural soils indicating the low nutrient content of forest soils. There is now strong evidence that the phosphate in forest soils exists in several forms which are in equilibrium with the soil solution. The form of phosphate estimated by extractants represents only a very small proportion of the total, and with soils of some lithological origins the phosphate removed by the addition of an extractant was rapidly re-absorbed, presumably as other forms.

A. WILLSON

Effects of Trees on Sites

Work has continued on a series of experiments jointly with the Institute of Terrestrial Ecology on the effects of intense harvesting on site properties. Methods have been developed using electrodes and rusting rods to determine the changes in soil oxygen and its effect on rooting following whole-tree harvesting.

M. ANDERSON

Lowland Forestry

Open-cast Mineral Sites: Nitrogen Nutrition

With the improvements to the physical conditions of spoils described in earlier *Reports* and now passing into practice, research emphasis is being focused on nitrogen nutrition of tree crops on sites where topsoils are inadequate or lacking.

Line sowings or plantings of legumes have been made on several spoils. Tree lupin (*Lupinus arboreus*) and the biennial Sweet clover (*Melilotus* spp.) appear sensitive to the low pHs in heath podzol topsoils. Defoliation by grazing animals is a severe problem, even though the plant material is not usually eaten; small seedlings even of unpalatable species have been destroyed. Tree lupin and Sweet clover establish fastest, Everlasting pea (*Lathyrus* spp.) more slowly. Mixtures of Sweet clover and Everlasting pea are now being tried. Other species being studied include *Astragalus glyphyllos*, *Galega officinalis* and *G. orientalis*. All of them are unpalatable to forest animals such as deer, rabbits and hares.

The severe winter of 1981/82 killed much of the above-ground parts of large tree lupin bushes, but they shoot again from ground level. Some small plants (<20 cm tall) appear to have died. Sweet clover and Everlasting pea have not been damaged, but branches of broom (*Sarothamnus scoparius*) and gorse (*Ulex* spp) have been killed.

The alders remain the most useful tree species able to grow without any nitrogen; they are also reliable because they succeed where others fail, for example on sites with the minimum physical amelioration. Even so, rooting problems, dieback, and root aphids do occur on wet, compact heavy spoils. Evaluation of the growth and nodulation of six *Alnus* species (*glutinosa*, *incana*, *cordata*, *rubra*, *sinuata*, and *viridis*) are being made on different sites.

D.F. FOURT, N. BEST

Open-cast Mineral Sites: Vegetation

In the absence of topsoil, most coal mining spoils are calcareous and after exposure follow a vegetation and soil development sequence which resembles a glacier tail. The material becomes decalcified and leached, losing calcium, phosphorus and potassium, but accumulating organic matter and fixed nitrogen. Whether or not the spoils are afforested, many develop an interesting and conspicuous flora, including orchids and herbaceous legumes, moving towards a base-rich woodland community.

D.F. FOURT, M. ANDERSON

Problem Sites: Calcareous Soils

It was formerly thought that trace element deficiencies (such as lime-induced chlorosis) were more important than deficiencies of major elements, but foliar analysis has identified sites on chalk soils low in phosphorus and potassium, due probably to depletive agriculture. Here there have been good responses to PK fertilisers. Nitrogen deficiency can also occur where trees are embedded in thick fescue mats. Nitrogen deficiency in such circumstances is best dealt with by herbicides, as fertiliser nitrogen merely benefits the grasses. Lime-induced chlorosis is confined to soils saturated at the surface with finely divided calcium carbonate and adequately supplied with major nutrients. It is common in thicket and pole-stage stands of both conifers and broadleaves, especially Scots pine and beech, rare in Norway maple, sycamore and ash and uncommon in Corsican pine and Red cedar, at least till the late pole stage.

A further problem of many calcareous soils is periglacial compaction, now known to occur on plateaux and upper slopes as well as on the more familiar Coombe rock sites. Conventional cultivation will relieve the compaction, but

the soil inversion which results may produce lime-induced chlorosis. Since this can be prevented by retaining the acid surface layer normally present (which may be only 5 cm thick), plain or winged tines, as recommended for reclamation work, should be used, followed by weed control along the ripper slots. Soils derived from Cretaceous chalk have adequate soil moisture storage and supply, unlike crystalline or bedded limestones.

D.F. FOURT. N. BEST

Upland Forestry

Drainage Trials

During clearfelling of the drainage experiment at Crychan Forest (Powys) sample trees from the top, middle and bottom of each plot were measured for mid-diameter and timber height. Daily borehole readings were modelled (*Report* 1980, p.25), characterising each plot by three drainage descriptors. All data were subjected to an analysis of variance. Small but significant differences were detected in both hydrologic and growth characteristics. This suggested that the original drainage had continued to influence hydrologic properties and had also influenced tree growth.

It is clear that the design and assessment of drainage trials has in the past been imperfect. The effects on growth which are sought for are likely to result from changes in drainage rate. However, most peaty gleys occur on slopes of varying angle and so drainage rate does not necessarily depend directly on drain spacing. Methods of analysis which seek to relate tree growth to drain spacing alone are therefore ill-founded. In the future growth or stability, or both, should be examined as a function of drainage *rate* rather than drainage treatment (depth and spacing). It is possible that past experiments have been inconclusive because of insensitive methods of measuring and analysing drainage and growth responses.

R. CARNELL

Advisory

Planting on old refuse tips continues to cause difficulties. Domes or ridges are suggested as the best means of coping with subsidence and improving drainage. However, heat produced by compacted and decomposing wastes may be an additional complicating factor. Old waste tips are best left undisturbed and, if drainage can be provided, older wastes with a high proportion of coal ash in them are a better growth medium than modern wastes, containing large amounts of paper and plastic, which need a much thicker cover.

W.O. BINNS. D.F. FOURT

SITE STUDIES (NORTH)

Classification and Improvement of Upland Soils

Clay soils

The experimental work at Kershope in collaboration with the Institute of Terrestrial Ecology (*Report* 1981, p.28) is now in full swing. During the first

1½ years preceding clearfelling most attention has been given to three matters: an assessment of the effect of the three ditch spacings on the water level in boreholes, the water balance of four of the plots, and the chemical composition of the soil water and ditch water.

Borehole water levels, whether calculated as long term means of weekly values or as rates of fall measured over a few days of dry weather, show a trend of increasing depth with decreasing ditch spacing (spacings are 40, 20 and 10 m), but these apparent treatment effects do not quite achieve statistical significance. A comparison of current data with measurements made in 1965–66 just before the ditches were dug, shows a similar trend and the amount by which water levels have fallen in the 10 m treatment is significantly greater than for the 40 m treatment. More analysis of the data for borehole water levels is needed to compare with data from soil tensiometers before firm conclusions are drawn. Table 3 sets out the water balance for 1981 calculated for three of the four “hydrology plots”. It is not yet possible to quantify the errors in the components of the water balance for each plot and accordingly average values for the three 2 ha plots are shown.

TABLE 3
WATER BALANCE 1981 (MEAN OF THREE PLOTS)

CROP: SITKA SPRUCE, TOP HEIGHT 18 M
UNITS: MM EQUIVALENT DEPTH OF WATER

Gross Rainfall	Throughfall	Stemflow	Net Rainfall	Drain Discharge (Runoff)		
P	T	S	$N = T + S$	R	N-R	P-R
1403	739	122	861	711	150	692

The difference (N–R) comprises transpiration, evaporation from the soil surface and any gains or losses to or from the plots. Since this estimate is derived as the difference between two much larger components, it is liable to the greatest proportional error. The difference (P–R) comprises the interception loss (P–N) and (N–R) and is therefore the estimate of total evaporative loss. Compared with a grass-covered area for which estimated evapotranspiration at this site might be 400 mm (Smith, 1976), the annual evaporative loss is increased by 73 percent and runoff is reduced by 29 percent. The mean water balance for the three plots is similar to results for Sitka spruce obtained by Law in 1956 and the Institute of Hydrology (Anon., 1976).

The chemical composition of the soil water shows a consistent pattern of spatial variation which is of about the same magnitude as the temporal variation at each site. The concentrations of calcium, magnesium, sodium and iron, and the pH, tend to increase with depth, especially in the mineral soil beneath the peat. The concentrations of potassium, ammonium and phosphorus tend to decrease with depth. Nitrate seems to show a peak concentration near the base of the peat layer. The composition and pH of the ditch water show little spatial variation, and it seems likely that the temporal

variation reflects the chemical composition of the soil horizons from which most of the water is derived, which in turn depends on the depth of the water table.

D. G. PYATT

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FOREST GENETICS

Testing

Pollinations

The 1981 pollination season was mixed, with virtually no flowering on larch and, for the first time since Sitka spruce programmes began 10 years ago, there was a complete absence of flowering in the two major clone banks of this species. The scarcity of spruce flowers allowed more effort to be given to the Scots pine and Lodgepole pine pollination programmes.

The Scots pine programme included an extension to the series of partial diallel crosses amongst the 60 clones known to have high general-combining-ability. Seed yields from earlier diallels and open-pollinated collections from selected progeny-tested clones have been abnormally low. The Lodgepole pine programme completed the series of single-pair matings between selected trees within a population of Queen Charlotte Islands, British Columbia (QCI) origin (*Report 1980*, p.27) with a further 102 crosses. Sixty single-pair matings were also made between selected trees within QCI and Telkwa and Smithers, Skeena River, BC origins. An additional 60 lots of Telkwa/Smithers pollen were collected to complete the programme in 1982.

During the 1981 season a total of 321 artificial crosses were made which involved 7,000 isolations and 16,463 female flowers and in addition 382 separate lots of pollen were extracted for current or future use.

A joint research project with the Forestry Department, Aberdeen University, was initiated in spring 1982. It is concerned with problems of collecting, handling, storing and testing the viability of larch pollen.

Forest Progeny Tests

Progeny tests planted during the year and replicated on three sites included: 46 open-pollinated and 55 polycrossed families of Sitka spruce; 22 Sitka spruce × White spruce hybrid families derived from four different White spruce (*Picea glauca*) polymixes based on different origins; and 90 Scots pine open-pollinated families.

For Lodgepole pine, 53 Long Beach, Washington \times Burns Lake, BC and 51 Burns Lake \times Long Beach provenance hybrid families derived from single-pair matings were put into test. Also incorporated in these tests were 20 open-pollinated families of the Long Beach mothers and 23 open-pollinated families of the Burns Lake mothers. These were included in order to compare performances as inter- and intra-provenance crosses. A further Lodgepole pine test, based on large plots and repeated on two sites, included 42 families derived from provenance-hybrid mothers crossed with pollen mixtures of the same provenance-hybrid population. Six provenance-hybrid populations were included, and the parent trees were selected from trees raised from controlled crosses made in 1959 and 1960. This test is designed to simulate the type of material which will be derived from seedling orchards in the future and it will provide a basis for estimating the amount of segregation in the F_2 generation.

Genetic correlations were calculated between 6-year height, 10-year height and 10-year breast-height-diameter for 83 half-sib Sitka spruce families in 16 forest progeny tests. Correlations were found to be very high in all cases; the slight loss in genetic gain from making selections at the sixth year instead of the tenth is far outweighed by the saving of four years. Narrow-sense family heritabilities were similar at both ages but coefficients of phenotypic variation were greater at six years than at ten years. Thus a higher selection differential is necessary when selecting at six years if the same selection intensity is to be maintained. Similar high correlations for Scots pine data were also found. Selections of parents to be included in both Sitka spruce and Scots pine clonal seed orchards are now made at six years. Investigation of genetic correlation with mature traits is continuing.

A sample of families in a nine-year-old Sitka spruce population-study progeny test (*Report* 1970, p.110 and *Report* 1973, p.85) on three sites was assessed for 17 branching characteristics. Parent-progeny regression gave very low to zero heritabilities for branch-length, branch-angle, stem-straightness and height. Narrow-sense heritabilities for single trees within progeny tests were highest for branch-angle (0.45–0.60) but much lower for other branch characteristics, for example, branch distribution (0–0.14) and branch number (0.07–0.12). Single-tree heritability for height at eight years was 0.25. The data collected aid description of juvenile characteristics which can be correlated with mature traits, such as timber quality, in later years.

Forest Clonal Tests

Cuttings were taken from a random sample of 91, eight-year-old Sitka spruce trees of QCI origin, rooted in a polythene house during 1980. The cuttings were planted out on a forest site in 1982, with 47 of the clones replicated on a second site. The test is designed to provide estimates of broad-sense-heritabilities for height, diameter and branch characteristics. From these, estimates can be made of the genetic gain achievable by the clonal propagation of individuals phenotypically selected from a base population derived from imported seed.

Grafting success in the rejuvenation experiment (*Report* 1981, p.29) averaged 86 per cent. There were no differences in survival rates between scions from old or young trees. The quality of the graft unions between the rootstocks and scions from younger trees were far superior to the unions

associated with scions from old trees. The resulting grafted plants developed exceptionally well and it was decided to re-graft second generation scions from 59 of them onto actively growing rootstocks in early July. The re-graft was made using the normal apical side-veneer technique, and not with fully lignified side shoots as scions. The grafts were placed in a wire cage covered with pre-wetted cheese cloth and kept under mist. A 75 per cent success was achieved. The remaining successful first generation grafts were left to overwinter and 393 re-grafts were made in February using both apical and lateral shoots.

Seed Production

Seed Stands

A further 337 ha of seed stands were added to the National Register during the year. These consisted of one Scots pine, two Corsican pine, two Lodgepole pine, three European larch, one Japanese larch and three oak sources. Ninety hectares of seed stands were removed from the Register on account of wind-throw or fellings. Eleven applications for the registration of new sources were refused on the grounds of size, quality, or risk of contamination by pollen from nearby unsuitable stands of the same or compatible species.

Seed Orchards

A 2.4 ha Hybrid larch orchard was planted at Culbin, Laigh of Moray Forest (Grampian) bringing the total area of established Hybrid larch orchards to 28 ha, most of which have been planted since 1977. The first commercial seed collections are expected to be made around 1986. A 6.6 ha Lodgepole pine seedling orchard composed of 104 families derived from single-pair matings between trees of south-coastal Washington and central BC origins was planted at Inchnacardoch Forest (Highland). A further 3.5 ha of clonal Sitka spruce orchards was started at Ledmore in Dunkeld Forest (Tayside).

Biochemical Variation

A Carlo-ERBA Fractovap 2151 gas chromatograph has been purchased, in which glass capillary columns may be used to achieve high resolution separation of a large number of terpenoid constituents of conifer oleoresin. The amplifier output is linked to a Spectraphysics DP 88 computing integrator ("Minitrator"). Preliminary work has identified the optimal column type and temperature programs for the oleoresin of different species. A 15 m long SE-54 column is generally the most effective for those species examined so far, and a sample throughput time of under 30 minutes can be achieved. From an average oleoresin sample, at least 100 peaks may be separated; a few of the monoterpene hydrocarbons and oxygenated monoterpene peaks have been identified by comparative runs of pure samples.

This equipment is being used in a joint project with Pathology Branch to identify any correlation which may exist between the susceptibility of Sitka spruce stumps to infection by basidiospore suspensions of *Heterobasidion annosum* and the terpenoid composition of the stump xylem and cortical oleoresins.

Other projects currently in progress include the correlation of oleoresin composition with morphological features of individual trees. Promising results have been obtained within certain provenances of Lodgepole pine.

R. FAULKNER, A.M. FLETCHER, G.I. FORREST, J.G.S. GILL

TREE PHYSIOLOGY

Root Growth and Form

Root Anchorage

Instrumentation of the soil/root plate in a Sitka spruce stand while force was applied to the stem by winching, indicated some of the detailed changes which occurred when the root systems were disturbed. For example, the sound of roots breaking was detected using buried microphones, and their numbers were estimated. Breakage occurred before inclination of the stem base reached 1°, and before the maximum force was attained to pull the tree over. Certain points of weakness were identified in the root system. On the windward side large numbers of small roots were broken under tension; radial growth of the roots at a distance from the tree, as well as the strength of the root wood, was clearly important. On the lee side small numbers of large roots were broken under bending and twisting forces, mainly at points of branching close to the base of the tree. Damage to the root system of winched trees could not be distinguished from that on windblown trees.

Root Development

Analysis of Sitka spruce root systems on two sites indicated that the final configuration of the woody root system was largely determined during the first six years after planting.

M.P. COUTTS

Mycorrhizas

Testing of fungi as symbionts with Sitka spruce continued through the year, and inter- and intra-specific differences in ability to form stable symbioses were noted. Some isolates formed mycorrhizas under gnotobiotic conditions, but seemed unable to do so in non-sterile soil. Others, whilst forming mycorrhizas initially, were later replaced by indigenous fungi. Yet others readily formed mycorrhizas which remained stable in unsterile soil.

In a joint project with the Institute of Terrestrial Ecology, two *Paxillus* isolates and *Laccaria* species were used to synthesize mycorrhizas with Sitka spruce seedlings potted into four non-sterile soils. Initial data indicate that all mycorrhizal plants grew better than untreated controls, and that plants inoculated with the *Laccaria* isolate (from the University of Surrey) were the largest.

Work is in progress on the inoculation of Sitka spruce cuttings in polythene greenhouses.

C. WALKER

Flower Induction

Experiments with mature grafted Sitka spruce, in a polythene house, provided an important confirmation of the observation that heat or drought can facilitate a good response to application of the gibberellin A_{4/7} mixture to induce male and female cones. GA_{4/7} is also effective when potted grafts in a polythene house are girdled, and trials have been established at Wauchope clone bank to test this observation in the field.

There is discussion in the literature of the idea that root stress is involved in the induction of flowering. Temperatures above 25°C are known to exceed the optimum for Sitka spruce root growth. Potted grafts placed in root heating boxes, to raise the soil temperature to approximately 35°C for four or eight days, produced an increase in male cones compared with unheated controls.

A sample of 11 kg of current year shoots was collected from four 47-year-old Sitka spruce trees. This sample will be used for analysis of endogenous gibberellins and other hormones, in a research programme to be initiated in the coming year, in collaboration with the Department of Botany, Glasgow University.

J.J. PHILIPSON

Vegetative Propagation

Young shoots of Sitka spruce, introduced into sterile culture at the cotyledon stage, extended and produced axillary buds during their development. The first subcultures derived from the primary cultures extended at the same rate, but those originating from apical buds produced axillary buds at more than twice the rate of those originating from axillary buds. After a second subculture, shoots that had been apices in the previous culture were able to proliferate buds at higher rates than those which had previously been axillary buds. In the second subculture, there was no correlation between the rate of extension and the origin of the subculture.

A. JOHN

FOREST PATHOLOGY

Dutch Elm Disease

Elm Regeneration

The survival of English elm (*Ulmus procera*) suckers continued to be assessed in southern England. During 1981 there was no overall increase in the mean disease level in undisturbed plots; losses being balanced by the recruitment of young suckers. Only 15.4 per cent of the suckers were diseased after 5 years of observations. Cumulative disease levels also remained low in the individual tree plots (5.1 per cent), (*Report* 1981, p.33) and in planted elms in motorway plots (7.5 per cent). Many of the infected trees in these latter plots survived for more than one year. Twigs from them yielded 202 isolates of the aggressive strain of *Ceratocystis ulmi* and four of the non-aggressive, as

determined by cultural characteristics (Gibbs and Brasier, 1973). On four sites, small cankers were found on twigs of English elm. From these cankers a fungus was obtained which closely resembled *Plectophomella concentrica*, previously only reported on wych elm (*U. glabra*) (Redfern and Sutton, 1981).

B.J.W. GREIG

Beech Bark Disease

Ecology of Fungi on Coccus-infested Bark

The microflora of bark infested by *Cryptococcus fagisuga* was found to include several fungi whose frequency of isolation was much higher than that of any others, and whose effect on the success of establishment by the bark pathogen *Nectria coccinea* may therefore be important. The fungus most frequently associated with live and recently dead *C. fagisuga* on very heavily infested bark was *Verticillium lecanii*. This known entomogenous fungus seemed to accelerate mortality of individual *C. fagisuga* detached from the tree. In culture, it also caused strong lysis of *N. coccinea* (Plate 4) and partial lysis of *Nectria viridescens*, the only other fungus apparently associated with the live insect. Long dead insect colonies were dominated by *Cladosporium cladosporioides* (Report 1981, p.35), low nutrient 'lawn' cultures of which were much more readily colonised by *N. coccinea* than by *Fusarium lateritium*. The latter fungus seemed to be a possible competitor of *N. coccinea*, since it was a constant part of the microflora, including that of bark lesions, and since it strongly inhibited the growth of *N. coccinea* in culture.

In a study involving artificially inoculated beech logs, *N. viridescens*, *F. lateritium* and a *Phoma* sp. invaded lesions caused by *N. coccinea*. There was no evidence, however, that this invasion caused any inhibition of lesion development.

D. LONSDALE

Root Grafting in European Oak

As noted in the Introduction, this study was conducted under an EEC contract. Research on oak wilt in the USA has shown that a number of techniques can be used to investigate the frequency of root grafting in oak stands. However, they all have some disadvantage being either destructive, laborious, or potentially hazardous to the operator. From our work it appears that the most suitable method is the injection of the herbicide cacodylic acid into a freshly cut stump, the surface of which has been sealed with an epoxy resin. Examination of the foliage of surrounding trees a few weeks later should enable a rapid determination to be made of those trees which are grafted to the injected tree. The nature of the functional grafts can then be determined by excavation.

*A.G. MITCHELL, J.N. GIBBS

* Sandwich student from the Department of Biological Sciences, University of Bath.

Spring Frost Damage on Sitka spruce

Sitka spruce in north and west Scotland was severely damaged in April 1981. Trees up to 5 m tall were affected. After four weeks of generally very warm weather at the end of March and the beginning of April, when daily maxima of 17–20°C were recorded on a number of occasions, a severe frost occurred on the night of 22/23 April. Screen minima of –10°C and –6.5°C were recorded at Glengarry Forest (Highland) and Mull Forest (Strathclyde) respectively.

Although very few trees had begun to flush when the frost occurred, old needles appear to have been de-hardened by the warm weather and, in many cases, cambial activity had begun. Damage was therefore confined to browning of older needles and to the death of cambium on branches and main stems. Buds generally remained healthy, and even trees with severe needle damage flushed normally. Trees which had been girdled by complete death of cambium on the main stem also flushed normally, but died back in early summer. In a minority of trees dieback continued to develop for the remainder of the growing season.

Cambial injury was most commonly restricted to the central one-third of the main stem, and to the branches arising from this region. Cambial tissues above and below this damaged zone generally remained healthy. This may have been related to the protective effect of the lower branches and to the physiological state of the tree at the time of the frost. In a provenance experiment at Farigaig Forest (Highland), Alaskan provenances showed significantly less damage than more southerly provenances. By late summer 1981, most trees affected by dieback had formed recovery shoots on healthy bark below the zone of injury. *Phomopsis conorum* Died. was present on dead bark but healthy callus had begun to form around lesions and there was no visual evidence to suggest that the fungus had invaded healthy tissue and caused lesions to extend.

D.B. REDFERN

Advisory Services

Southern England and Wales

Spring 1981 was very wet in much of England and Wales and this is reflected in the many inquiries received on leaf pathogens including *Drepanopeziza sphaeroides* on *Salix alba* 'Tristis', *Venturia chlorospora* on *S. fragilis* and *Venturia inaequalis* on Flowering crab apple (*Malus sylvestris*). Prolonged dry weather later in the summer caused leaves of many broadleaved species, and the older leaves of Lawson and Leyland cypresses to brown and fall, especially where the trees had suffered the additional stress of aphid infestation, transplanting or undercutting.

Microsphaera alphitoides was exceptionally severe on large oaks throughout the summer. Unusual records concerned *Ophiognomonia pseudoplatani* on sycamore in Gloucestershire and *Meria laricis* on P.64 larch in Devon. *Microstroma juglandis* (Bereng.) Sacc. was seen causing yellow leaf blotches on a 2 m tall walnut (*Juglans regia*) in Somerset. We can find no published account of its occurrence in Britain, although the Commonwealth Mycological Institute holds collections for England dating from 1951 and later years.

Severe bud moth injury markedly delayed flushing and reduced subsequent

foliage density of many ash. Many buds with only slight insect damage had also died, apparently killed by *Nectria galligena*.

In Somerset a large Horse chestnut (*Aesculus hippocastanum*) was killed by *Verticillium alboatrum* Reinke & Berth. This was one of the few records of damage to trees by this fungus and only the second British record of any *Verticillium* wilt on *Aesculus* (Report 1976, p.34). In Clwyd, annual stem cankers on 20-year-old Japanese larch, all dating to the dormant period 1973/74 and centred on brashing wounds, closely resembled those attributed by van Vloten (1952) to *Phomopsis pseudotsugae* (now *Potebniamyces coniferarum*).

Stereum rugosum was invariably present in large perennating stem cankers on 25-year-old Red oak in a Hampshire plantation. Earlier workers (e.g. Banerjee, 1956) have provided some evidence of a causal relationship and experiments are in progress to confirm this.

Phytophthora citricola severely damaged 1–2 m tall container-grown *Nothofagus procera* in Surrey and many second year plants in a Shropshire nursery.

Fomitopsis pinicola (Fr.) Karst. was found for the first time in Britain. It was growing on a fence (either larch or spruce) in Surrey.

R.G. STROUTS, T.C. REFFOLD, D.R. ROSE

Scotland and Northern England

Lophodermium seditiosum on Scots pine, and *Armillaria*, were the two most frequently recorded pathogens. Foliage diseases of broadleaved trees were particularly common and included *Cristulariella depraedans* on sycamore, *Gloeosporium quercinum* on oak and one case of a relatively unusual leaf spot disease of lime caused by *Cercospora microsora*.

Necrosis of the cotyledons of young beech seedlings, leading in some cases to death of the seedlings, was found to be associated with *Mycocentrospora acerina*. This fungus was first described by Hartig (1880) as a pathogen of *Acer* seedlings and was later found to be a serious pathogen of a variety of non-forest crops (Sutton and Gibson, 1977). This is believed to be the first record from *Fagus* and the pathological status of the fungus is under investigation.

The frost on the night of 22/23 April which severely damaged Sitka spruce (see p.27) caused only minor damage to other conifers.

D.B. REDFERN, S.C. GREGORY, J.D. LOW

Tree Seed Pathology – Overseas Development Administration Contract

The following fungal species isolated from seeds of *Pinus caribaea*, *P. oocarpa*, and *P. pseudostrobus*, were pathogenic when introduced to tropical pine saplings: *Botryodiplodia theobromae*, *Botryosphaeria ribis*, the *Colletotrichum* state of *Glomerella cingulata*, *Fusarium equiseti*, *F. merismoides* var *acetilereum*, *F. moniliforme*, *F. moniliforme* var *subglutinans*, *F. oxysporum*, *F. semitectum*, *F. solani* and *Macrophoma sapinea*.

Proof that *Botryodiplodia theobromae* can be internally seed-borne was demonstrated with *Pinus caribaea* seed from Nicaragua. The pathogen grew from aseptically excised endosperm and/or embryo, but not from the testa which had been cleaned of microflora by surface sterilization. In some seeds

B. theobromae had destroyed the embryo and can therefore be classified as a true seed pathogen.

Mycological work with non-indigenous fungi isolated from seeds of tropical pines during this research project is authorized by Ministry of Agriculture licence number PHF 68/21.

A.A. REES

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FOREST ENTOMOLOGY

Population Studies

The Web-spinning Larch sawfly, Cephalcia lariciphila

Damage by the sawfly has continued to decline and was only appreciable at Ystwyth Forest (Dyfed). The ichneumonid parasite *Olesicampe monticola* is now widespread in all former infestation areas.

D. J. BILLANY

The Pine Beauty Moth, Panolis flammea

This pest is currently at low levels throughout the Lodgepole pine plantations of Scotland and northern England. Population monitoring by pheromone trapping is continuing, supplemented by pupal surveys where further information is required. Work was begun on two study-plots in Shin Forest, N(S) and Naver Forest, N(S) to measure changes in population density through successive stages of the life-cycle of *P. flammea*. Life-tables were constructed which showed, for each plot, the densities at each of nine stages. One population showed an increase over the generation, the other a severe decrease. The largest single mortality factor in both cases was that acting on the late-stage larvae.

J. T. STOAKLEY, D. BARBOUR

The Pine Looper Moth, Bupalus piniaria

Populations of *B. piniaria* were sampled in the same manner as previously described (*Report* 1980, p.37) but at a reduced number of units following the analysis of past data carried out by Dr D. Barbour (*Report* 1981, p.39). Increased numbers have been recorded at 21 of the 39 units sampled and only eight remain unchanged from the 1980/81 counts. Cannock (Staffs) continues to have the highest population, moving up from 3.2 to 5.6 pupae per m².

R. M. BROWN

Host Plant Susceptibility*Green Spruce Aphid, Elatobium abietinum*

Spruce species and provenances that show differences in aphid relative growth rates are being analysed for biochemical components that may affect aphid performance. The Asiatic spruces with a lower aphid relative growth rate have a greater concentration of phenolic compounds than the susceptible North American species, and this may account for observed differences in attack.

Lime Aphid, Eucallipterus tiliae

Following screening tests for resistance of certain species of lime to the Lime aphid, the scanning electron microscope is being used to determine the structure and function of certain leaf-surface features that appear to influence resistance to the aphid. Two types of resistance mechanism are under investigation. Some species possess leaves with dense stellate hairs that act as a physical barrier. Others have small glandular prominences on the minor veins which apparently prevent the aphids from feeding.

C. I. CARTER, J. F. A. NICHOLS

Biological Control*Rhyacionia buoliana*

Mating disruption experiments on Pine shoot moth at Kilveyhill, Coed Abertawe (W. Glamorgan) and Mayday Farm, Thetford (Norfolk) (*Report* 1981, p.41) were repeated. The chemical E-9-dodecenyacetate (E9DDA) was dispensed from Conrel fibres and the results, which support those obtained last year, showed that trap catches in treated areas were reduced by 99.9 per cent (Kilveyhill) and 100 per cent (Mayday Farm) compared to controls.

A new trial was started in infested Scots pine on Salisbury Plain. The object was to compare the efficiency of the pheromone (E9DDA) when dispensed by Microcaps (microencapsulated formulation kindly supplied by Plant Protection Ltd., Jealotts Hill), and by Conrel fibres. Microcaps suspended in water were applied over an area of about 7 ha with an ultra-low-volume applicator (ULVA 8) at 5.4 g ai/ha. A similar area was treated with Conrel fibres attached to trees (5.4 g ai/ha) and a further 7 ha was untreated. Release rate of the pheromone from the two formulations was similar. Trap catches in the treated areas were reduced by 96.5 per cent (Microcaps) and 100 per cent (Conrel fibres) compared to the control area.

*C. LONGHURST, D. J. BILLANY

* Chemical Entomology Unit, Southampton University

The Pine Beauty Moth, Panolis flammea

Sex-attractant pheromones of *P. flammea* were dispensed in Conrel fibres within Lodgepole pine plantations at Helmsdale (now Naver) Forest (Highland) in an attempt to disrupt mating.

Pheromones were applied singly and in combination, at different release rates, within small plots, and all treatments significantly ($P < 0.001$) reduced pheromone trap catches compared to untreated controls. Dissection of females caged with males in some of the treated and control plots showed a higher frequency of unmated females in the treated plots.

J. T. STOAKLEY, *C. LONGHURST

Chemical Control*The Pine Beauty Moth, Panolis flammea*

In late May 1981, 66 ha of Lodgepole pine in Helmsdale (now Naver) Forest were treated by ultra-low volume (ULV) aerial application of fenitrothion at 300 g ai/ha, under clearance from the Pesticides Safety Precautions Scheme. Application of the insecticide by helicopter was facilitated by modification of spray equipment to produce the small droplet size appropriate for low flying speeds. Following an investigation of edge effects in ULV spraying by the Ecological Physics Research Group, Cranfield (*Report* 1981, p.41), a new prescription for aerial application on windward edges of plantations was followed in this operation. This resulted in a high level of control over the whole area.

J. T. STOAKLEY

The Pine Weevil, Hylobius abietis

An investigation was carried out at Bowland Forest (Lancashire) to determine the rate of loss of gamma HCH from the lower stems of Sitka spruce transplants dipped in the standard treatment of 1.6 per cent Gamma-Col solution prior to planting. Plants dipped and planted in winter lost 62 per cent of the applied gamma HCH within about 10 days and by the time of expected first attacks in late April had lost 85 per cent of the original insecticide. Plants dipped and planted in spring lost 50 per cent of the original dose within about 10 days. Plants from both treatments contained less than 2 per cent of the applied insecticide on the lower stems at the end of the season. These results are comparable to data obtained in an investigation in Sweden (Eidman *et al.*, 1979).

J. T. STOAKLEY

Scolytids*The Synthetic Aggregation Pheromone of Xyloterus (Trypodendron) lineatum (Olivier): 'Lineatin'*

Following experiments with lineatin during 1980 (*Report* 1981, p.41) a further evaluation of this pheromone was made in Dartmoor Forest (Devon) in 1981. The response of flying *X. lineatum* to the optically pure isomers of 4, 6, 6 – lineatin, separately and in mixture, and the mixed isomers of 4, 5, 6 – lineatin, was tested. The pheromones were deployed on white plastic fin sticky traps in

* Chemical Entomology Unit, Southampton University

a randomised block design. The results show that the beetles responded strongly to both (+) and (\pm) 4, 6, 6 – lineatin but not to its (–) isomer or to (\pm) 4, 5, 6 – lineatin. This response compares very closely to that of N. American and European populations of this beetle and indicates that (\pm) 4, 6, 6 – lineatin may be used with confidence to trap these beetles.

C. J. KING

Chemical attractants for Scolytus scolytus (F.) and S. multistriatus (Marsham)

Further field experiments were undertaken during 1981 to evaluate the role of beetle and host (elm) produced substances in the chemically-mediated behaviour of *S. scolytus* and *S. multistriatus*. Beetles were trapped on disposable sticky fin traps made from corrugated white P.V.C. They were cheaper and easier to use than previous traps.

Trials with all four isomers of multistriatin have shown that one bait releasing 4-methyl-3-heptanol (120 $\mu\text{g/day}$) together with small amounts of the mixed isomers of multistriatin (c. 15 $\mu\text{g/day}$) can be used to attract populations of both *Scolytus* species (Blight *et al.*, 1983). This attractive bait was also tested in combination with the host substances (–)- α -cubebene, (–)-limonene and (–)- β -pinene in a factorial experiment. Addition of host substances did not increase catches significantly, in contrast to previous results (Report 1981, p.42). Present results may have been confounded by volatiles from nearby elm trees.

The chemical 4-methyl-3-heptanone, which is produced by male *S. scolytus* and female *S. multistriatus*, attracts walking *S. scolytus* of both sexes (Blight *et al.*, 1982a, b). When this compound was released in the field in high concentration (655 $\mu\text{g/day}$) in combination with 4-methyl-3-heptanol and (–)- α -cubebene, the trap catch of both *Scolytus* species was reduced compared to 4-methyl-3-heptanol and (–)- α -cubebene alone.

*M. M. BLIGHT, N. J. FIELDING, *N. C. HENDERSON, C. J. KING. *L. J. WADHAMS

Advisory Services

Forestry Commission staff sent 94 enquiries to Alice Holt and 41 to the Northern Research Station. The number of private enquiries received was 249 at Alice Holt and 30 at the Northern Research Station.

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*ARC Unit of Invertebrate Chemistry and Physiology, University of Sussex

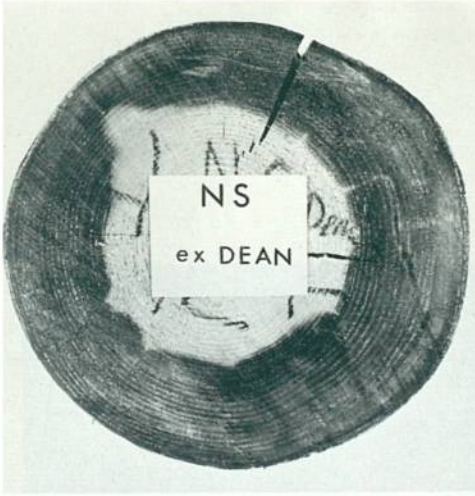
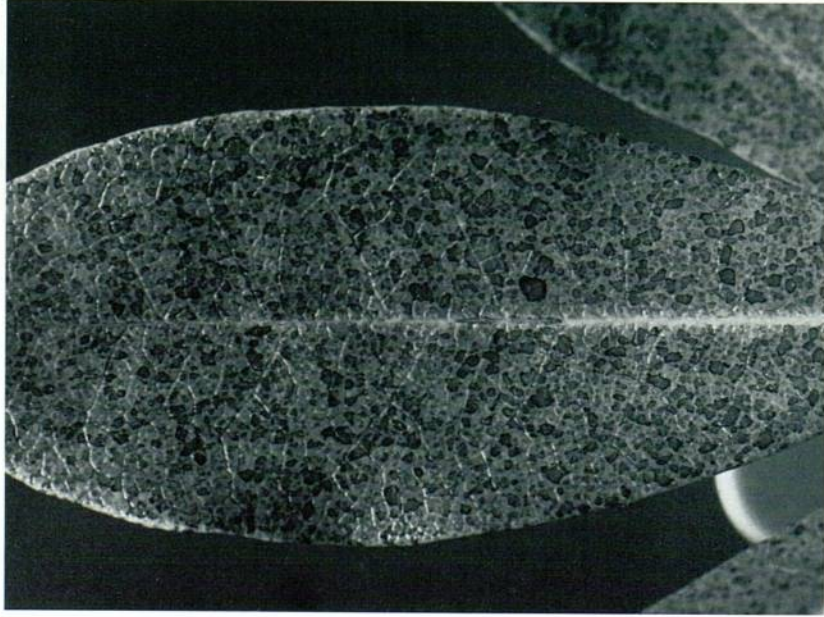


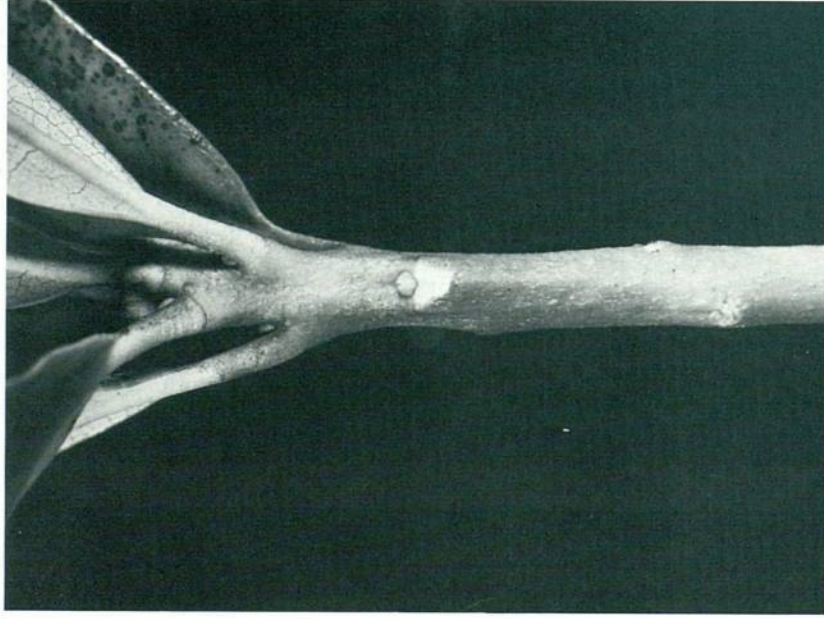
Plate 1: Spruce power transmission poles: Joint project with Electricity Council (p.44).

The successful treatment of spruce poles with preservative depends largely upon the proportion of the more permeable sapwood. Norway spruce (top) usually contains an adequate depth of sapwood. Sitka spruce is more variable and selection of poles with sufficient sapwood is necessary. The pole from the Forest of Dean displays only a few millimetres of sapwood and is unsatisfactory, but the pole from Ringwood (bottom) where nearly half of the radius is sapwood is acceptable.

Plate 2: Spray deposits on *Rhododendron ponticum* from herbicide solution applied conventionally at 250 l/ha (p.50).



A: Leaf, when sprayed with 2 kg ai/ha of hexazinone as Velpar L.

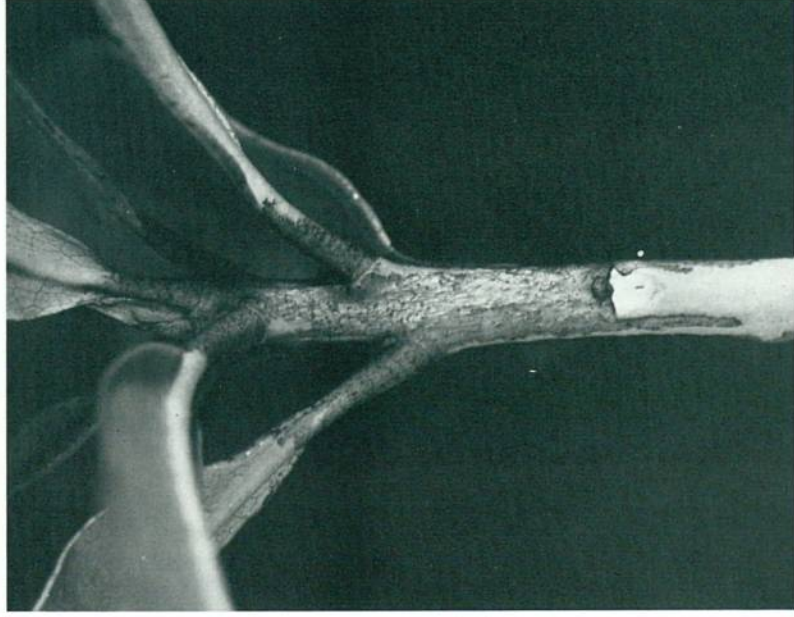


B: Stem, when sprayed with 2 kg ai/ha of hexazinone as Velpar L.

Plate 3: Redistribution of spray deposits on *Rhododendron ponticum* due to the addition of Mixture 'PB' to the herbicide solution, applied conventionally at 250 l/ha (p.50).



A: Leaf, when sprayed with 2 kg ai/ha of hexazinone as Velpar L + 10% v/v Mixture 'PB'.



B: Stem, when sprayed with 2 kg ai/ha of hexazinone as Velpar L + 10% v/v Mixture 'PB'.

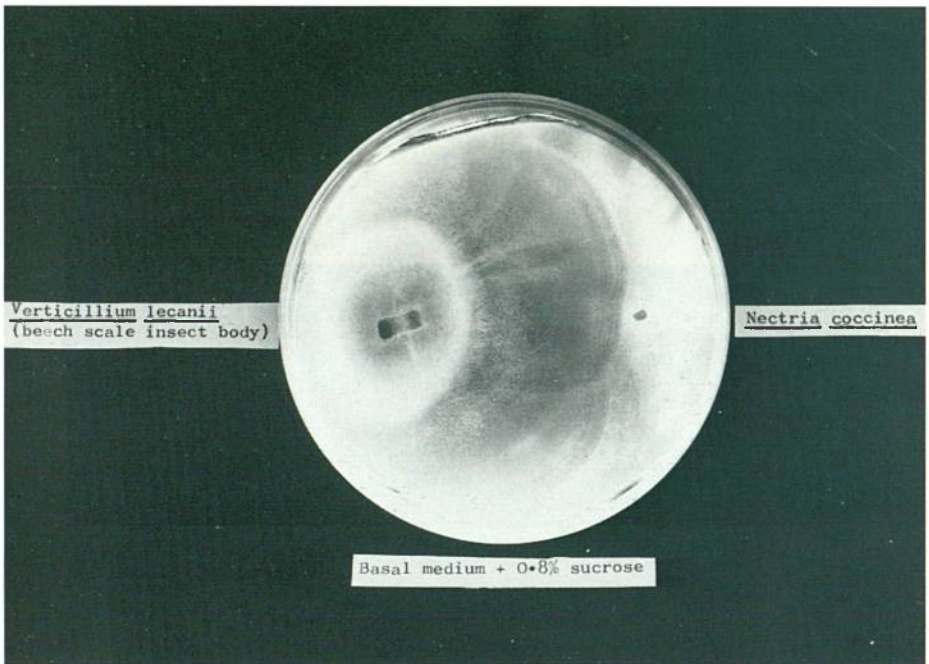


Plate 4: A. Lysis and invasion of an agar culture of *Nectria coccinea* by *Verticillium lecanii* which was isolated from bodies of the beech coccus. A 10365.

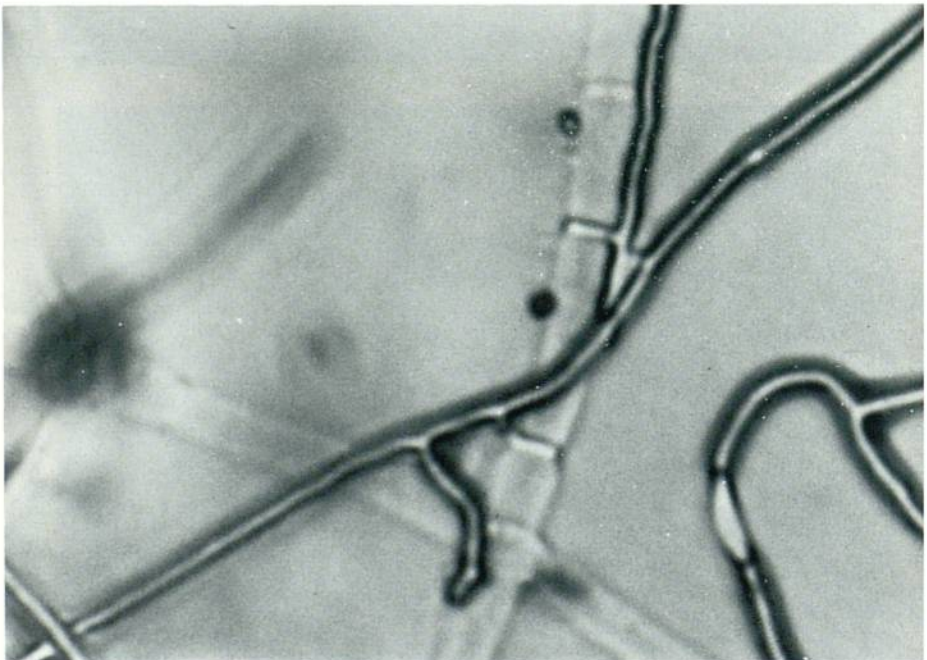


Plate 4: B. Micrograph of individual hyphae, showing the apparent loss of contents from those of *N. coccinea* (wider hyphae). (p.26). A 10366

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WILDLIFE MANAGEMENT

Management of Deer, Squirrels and Other Mammals

Red deer research has concentrated on estimating deer densities in a wide range of forests. Dung group counting is proving more useful than expected. Vantage point counting can be useful but the period of observation must exceed three hours. Red deer densities of 10-15/km² have been determined locally. Identification of food plants from rumen samples has been completed but chemical analyses have still to be carried out. The use by red, roe and sika deer of re-seeded and fertilised deer control glades is being monitored for North Scotland Conservancy.

Roe deer research has concentrated on techniques for linking deer activity and density with forest structure. Capture techniques have been reviewed and marking has continued at Chedington (Dorset) and Thetford (East England) as part of the long-term roe population studies. At Thetford a marked muntjac population has also been established. Routine age determination has incidentally shown a variable proportion of lower jaw dental abnormalities in different roe deer populations.

Tree squirrel management has been reviewed and work on reproductive inhibitors carried out in collaboration with Reading University. The annual squirrel questionnaire showed little increase in damage in state forests compared with the reports from private estates. This is partly due to the new requirement that fresh squirrel damage is measured using the nearest neighbour technique, which leaves little room for subjective assessment. A report that bark stripping by grey squirrels could be prevented by presenting salt licks has been tested. Bark stripping was observed in the presence of both plain and mineralised salt licks.

Bird Studies

A review of the literature on Holarctic woodland bird populations is nearing completion. Studies of the management and ecology of tawny owls and of goshawks in extensive upland spruce forests have been initiated. A population indexing technique for small mammals, particularly *Microtus*, is being developed for wider application in upland predator studies, and for predicting cyclic patterns in relation to damage. Analysis of a winter bird community study in a lowland forest has provided information on the use of different types of forest structure by species and species groups.

Damage Assessment and Evaluation

Work is concentrated on two major areas: determining the relationship between animal densities and damage levels, particularly of deer, and looking at the response of crops on different sites to similar types and levels of damage. In addition a number of special surveys have been carried out. At Delamere, grey squirrel bark stripping on Corsican pine resulted in a loss of about £18 per ha in thinning revenues. *Eucalyptus* varieties expected to be damage-resistant were readily taken by roe deer in an enclosure. Comparison of fenced and unfenced Sitka spruce in West Scotland showed that 66 per cent of the leaders had been lost to roe and red deer browsing within two years without killing the trees. Simulated bark stripping on Lodgepole pine and Sitka spruce in 1978 has not depressed growth of trees. On the Lodgepole pine plots 3 per cent of the trees have snapped off at the wound site and 3 per cent have occluded and grown new bark, probably owing to an excessive resin flow immediately after bark removal. Use of a bark scarifying tool to reduce bark stripping by red deer showed that the tool itself could inflict considerable damage. A new version of this tool will be tested but the technique is labour-intensive.

Chemical and Mechanical Repellants

Tests of the high tensile nets now being imported into the UK suggested that, while they were adequate for deer farming or for flat straightforward fencelines, they had disadvantages in most forest conditions stemming from lack of flexibility when dealing with undulating ground and the heaviness of the rolls of wire and of the net strainer. Labour costs of erection were very much higher (£2 per metre when erected by contract staff) than had been indicated in the sales literature. The long-term experiment looking at the durability of metal fence components has shown that only the lightest gauge 36" × 3" × 19g hexagonal mesh netting has disintegrated at all three areas: at four years on the industrially polluted site, eight years on the coastal, salty site, and at 10 years on the control site.

Individual tree protection has continued with tests of the Spanish Comb. This little plastic, spiky device clips around the leading shoot and was effective where it remained on the trees. However, about half of the protectors came off over the four month trial period in the roe deer enclosure. The cattle guards (*Report* 1981, p. 43) were satisfactory until the 1981 floods washed away both trees and guards. This experiment will be re-established in 1982.

One chemical repellent, "Winter Forestry Latex" from Belgium, was tested. It may be as effective against roe deer browsing as Aaproctect but as it is a paste formulation the smearing application makes it more labour intensive and confines its use to broadleaved trees. Smearing conifers deposited too much repellent on the shoots and rainwater and snow caused them to bend over and sometimes break.

ENGINEERING SERVICES**South***Design and Manufacture of Equipment*

Two vent control units for the Cambridge greenhouse have been designed and built to our specifications by E.S.L. Engineering Ltd., Basildon. The units are an improvement over those commercially available, being safe and fully adjustable both in temperature range and differential. E.S.L. will market the unit at home and abroad in the next twelve months.

A tripod mounting complete with battery lighting system for an optical microscope has been made. Examination of insect populations on tree bark can now be made under poor light conditions in the field.

An aluminium heating block for 40 test tubes was made for the analytical laboratory. The heating elements are cast in as an integral part and there is direct temperature feedback to the solid state controller. In this way temperatures can be accurately maintained and corrosion minimised.

Maintenance of Existing Equipment

A Cambridge greenhouse has been completely rewired during the year to improved standards of safety and control.

Two of the seed germinating tanks have now been modified to a simpler design and a consequent improvement in reliability is expected.

Further extensions and re-allocations for the PRIME computer have continued to occupy a large proportion of time.

R. CARNELL

North*Manufacture and Repair of Research Equipment*

Eighty jobs using plastics, wood and metals were completed during the year. New equipment included transparent PVC louvred doors for polyhouses, where the louvres are spring-loaded and hinged at the bottom to throw the incoming cold air upwards. This prevents chilling and drying of plants near the door.

Over 60 electrical jobs were done, ranging from mains socket installation to complete rewiring of some greenhouses. These incorporate space and soil heating, ventilation, lighting, misting and associated control equipment.

About 15 new electronic circuits were constructed, ranging from an audio dipstick for measuring the water level in boreholes, to a sequential mist control unit for a large vegetative propagation polyhouse at Newton Nursery (Grampian) designed to raise 100,000 rooted conifer cuttings each year. This latter unit senses changes in air humidity using wet and dry thermistors, and switches mist jets on for a few seconds every few minutes when the humidity falls below a pre-set level.

J. ATTERSON

FIELD SURVEYS BRANCH

FIELD AND SITE SURVEYS

The Census of Trees and Woodlands and surveys for crop valuation and preparation of maps for plantation sales, have interrupted normal survey work everywhere to some degree. Staff were employed on data checks in forests not currently in the survey programme in preparation for the 1982 forecast of production. As a result surveys of only some 32,000 ha were completed in 27 forests.

Site survey work in Scotland was divided almost equally between the plantable reserve and established forests covering some 12,000 ha. In addition, 6,000 ha of forest were assessed for windthrow hazard largely on the basis of earlier site surveys. In England and Wales, Field Survey teams continued with their broad assessment of site over some 11,000 ha.

Production Forecasting and Forest Data Base Development

Crop data were updated to 31 March 1981 and the revision and checking of forecasting programmes supplied by Statistics Branch was completed in due time for the running of the quinquennial forecasts. A great deal of data updating was required and the incorporation of the revised data caused some delay to the first forecast run.

CENSUS

Field work in England and in North and East Scotland Conservancies was completed. South Scotland and Wales were 50 to 60 per cent complete, while work in West Scotland had barely begun. Data processing is now well advanced and computer programmes prepared by Statistics Branch were running satisfactorily for the basic estimates. It is expected that data checks and county estimates will take a further year to complete for Great Britain.

MENSURATION

Advisory work and services to the field take up a good deal of the time of this section. The sample plot data base was virtually complete by the end of the year. Plans have been laid for analysis but this task depends upon the availability of suitably qualified staff. Work on electronic field data capture devices proceeds with some delays due to problems with contracted computer programmes.

DRAWING OFFICE

Work on Census maps was finally completed by September 1981 and aerial photographic requirements for this activity were well served during the year.

A second stereo plotter for aerial survey work, a Wild B8S, was installed in preparation for computer aided mapping. Work in further preparation for this development has proceeded satisfactorily.

WORK STUDY

Forest Management: Method Study

A comparison of two lining out machines has been started as part of an examination of several aspects of nursery practice. The objective is to define which system offers optimal quality of planting and spacing in the lines, as well as giving output and ergonomic advantages. Further trials of the Zijlstra and Bolhuis nursery plant lifter were carried out after some modifications. Results still indicate plant size as a constraint, but a range of species have been lifted successfully on a variety of nursery soil conditions. A survey of plant handling methods was initiated with the objectives of identifying where system improvements are necessary and how best to integrate mechanised lifting into the nursery. The design of planting bags was examined.

Evaluation of the Excavator rotary ditcher was completed. Early mechanical problems were resolved, and the machine is recommended for maintenance of drains on many mineral soil site types. Work to further improve certain aspects of the motive unit is continuing.

Forest Management: Servicing and Continuous Review

The Ulvaforest, a tractor-mounted controlled drop applicator designed specifically for forest conditions, was given extensive trials and proved effective, although certain modifications were made as a result of field experience. Work on various forms of alternative herbicide applicators continues and veterinary drench guns modified for medium volume spot application show considerable promise. Direct applicators, for either pedestrian or tractor-mounted use also show good results for specific weeding situations.

Trials of clearing saws during the year included the Husqvarna 244R and Jonsereds RS45. A spray attachment for the Husqvarna 165R clearing saw was developed which permits a measured dose of herbicide to be applied during the cutting operation.

Full assistance was given to Education and Training Branch in the training of staff and introduction of foam fire fighting equipment in several Conservancies. A polycarbonate visor to fit the standard helmet is under test as an aid to fire fighting teams.

Forest Management: Work Measurement

An output guide on the use of the Micron Herbi controlled drop applicator was issued, and studies for the production of an output guide on granular herbicide application have commenced. An output guide on restocking using the Finnforester tree planter will be published shortly.

Harvesting and Marketing: Method Study

A full programme of machine evaluation was undertaken including detailed study of integrated working systems where appropriate. The following machines were among those examined: Valmet 862K Forwarder, Bruunett Maxi 858F Forwarder, Lokomo 919 Forwarder, Valmet 450 (Skogsjan) Grapple Processor, Gremo TH25 Harvester, Bruunett Mini Processor, Kockums 822GP Processor, Valmet 882K Clambunk Skidder and Kockums

880 Feller Buncher. Studies on a privately owned Makeri Harvester were also carried out.

An examination of clearfelling methods for crops on slopes in excess of 40 per cent has led to systems which not only compare favourably in terms of outputs and costs with conventional methods but are safer and ergonomically correct.

Trials have taken place with the Smith Timbermaster Line Pay-off carriage which was redesigned and now shows initial promise.

An examination of man made fibre strops in cable crane rigging, in place of the heavy standard steel types, is in progress.

A system review of timber movement to define optimum relationships between skidders, forwarders and lorries in East Anglian forests was completed.

An examination of systems of processing pitwood and fencing material in Wales was completed and, after the successful development of a mechanised pitwood depot in Yorkshire, further work on determining output guidance is current.

Harvesting and Marketing: Servicing and Continuous Review

The examination of new chainsaws and alternative guidebars and chains continues, and the following items were tested during the year: Husqvarna 266SG Chainsaw, Husqvarna 133SG Chainsaw with Oregon 0.325" pitch Prolite guidebar and 0.325" pitch Super Guard (34LG) chain, and Stihl 038 Chainsaw with Rollomatic guidebar and Topic super chain.

Much effort has been devoted to the installation and development of effective shortwood working throughout the country and, in conjunction with the Education and Training Branch, the introduction of forwarder harvesting methods has been successfully achieved.

Harvesting and Marketing: Work Measurement

A standard time table covering shortwood working in all species was issued as were standard time tables on hydratong extraction (by Massey-Ferguson 135 and 550 tractors) and crosscutting of 3 metre pulpwood at roadside.

An output guide on the Bruunett 578F Forwarder was published, and studies completed on extraction by 10-tonne class forwarders which will be issued shortly.

Studies of hand peeling of telegraph poles were completed, and the possibility of achieving peeling by mechanical means is being investigated.

Some studies were completed on the Tree Farmer C4D winch skidder which indicated an output broadly similar to the Timberjack 200 series.

Forestry Authority

A new form of data collector is under trial which offers greater operational flexibility and practical convenience. Initial results are promising but it has yet to be exposed to sustained field usage.

Investigations into noise dose meters and carbon monoxide meters and their application to forest working conditions are continuing.

Safety

Draft Forestry Safety Council Guides have been reviewed and comments submitted. Work Study Branch and Education and Training Branch staff have met regularly with the Safety Officer to ensure a co-ordinated approach to safe working techniques.

A.J.G. HUGHES

STATISTICS AND COMPUTING**Data Preparation and Computing**

Alice Holt Lodge

The previous year's demands on the PRIME 400 led to installation of one 80 Mb disk drive, a magnetic tape drive and a third 16-line synchronous communications adapter early in the year. A second 80 Mb disk-drive was added later. Demands also led to the computer being left running at weekends regularly, as well as overnight. A simple method of archiving and retrieving users' files using magnetic tape was introduced. Towards the end of the year an extension of the 1 Mb memory to 1½ Mb and an upgrade of the central processor to a PRIME 550 became necessary despite restrictions on the running of phantom jobs during the normal working day.

Northern Research Station

A DEC standard LSI 11/23 with 16 data ports was installed as a Terminal Control Processor (TCP). This links by a 4.8 Kb line to a node in the Edinburgh Regional Computing Centre's (ERCC) network of computers. Satellite equipment now includes a Decwriter iv console, a Printronic 300 lpm upper and lower case printer, three Hazeltine Esprit terminals, two Intertec Superbrain QD microcomputers, one Epson MX-80F/T dot-matrix printer and a Tektronix 4051 graphics terminal. The microcomputers are used both to prepare data on diskettes and to operate as remote terminals for entering the data to the network. Peripherals have been set up to public rooms (e.g. laboratories) rather than private offices, to encourage effective sharing.

UCSD PASCAL IV, a general programming language for microcomputers, is used to provide operating support for software, controlling communications between micro-computers and the ERCC mainframe computers.

Statistical Service to Research and Development Projects

Advice on experiment design, analysis and interpretation of results, continued to take up much of the statisticians' time. Powerful computing systems and software are now readily available to research project leaders via computer terminals. The benefits to them of 'hands-on' experience of computer analysis of their data have to be weighed against the risks of methodological errors in analysis and interpretation. The need both for statisticians to be consulted and for them to collaborate more intimately in research projects has never been so great.

The 'Autoreport' data analysis system developed for Work Study Branch was provided for routine use by their staff. The system was extended to include provision for data transmitted by a new time-study data-logging device, the Microfin.

An experiment to investigate the effects of various herbicide and mulching regimes on the establishment of trees on motorway sites had also been assessed for frequency of occurrence of the eleven most abundant weed species. Correspondence analysis was used to study the changes in relationships between the weed species and treatments over a three year period.

Using regression a large collection of Lodgepole pine provenance data was explored for relationships between seed origin in North America and site factors in Britain.

Statistical Service to External Units

A sample survey of chainsaw operators was proposed by the Safety Officer to estimate the incidence and severity of Vibration Induced White Finger (Reynaud's Disease). Advice was given on the design of the questionnaire, the sample and on the method of analysis. Help to the Unit of Invertebrate Chemistry and Physiology at Sussex University was again given in the design and analysis of field experiments.

Programming Service: General

Staff of many branches co-operated in the planning of a database containing a register of experiments to ensure that both research stations may enter information and phrase queries using a common vocabulary and conventions.

Alice Holt Lodge

The task of mounting all sample plot data files on the Rutherford/Appleton Laboratory IBM 195 was completed and the suite of programs available now allow easy retrieval of selected data as required. After the redesign of the production forecasting system using Jackson's Structured Design Method, the programs were completed and the results produced. Several databases to serve both management and research have been developed using the RAPPORT database system, and with notable collaboration from the Mensuration Section of the Field Surveys Branch.

Northern Research Station

A PASCAL program, written for the Superbrains, has smoothed the transfer of data preparation to these machines by simulating the old IBM drum card. In co-operation with staff of ERCC, tests of the RAPPORT database system have been planned.

Programming Service: Mathematical/Statistical/Technical

Alice Holt Lodge

The Census of Woodlands estimation programs were further developed and made fully operational. The software includes a facility which incorporates the calculated estimates into skeleton tables which are spooled to a high-quality printer ready for publication. RAPPORT was used to allow easy

and efficient access to the data for private and Forestry Commission woodlands. Flexibility was built into the estimation system allowing different estimators to be used easily when some assumptions were not met. Many graphical routines have been written for the Calcomp 1012 plotter to aid in data analysis and display. These include annotated pie-charts and shaded histograms. A routine using an efficient point-in-polygon algorithm which determines the county corresponding to a grid reference was used as part of the comprehensive validation system for the private woodlands data.

Northern Research Station

A GENSTAT program was developed to break down sums of squares and products into relevant components for estimating genetic correlations. A robust regression program (McNeil, 1977) was developed to fit either regression coefficients or block and treatment effects to a data set. It detects outliers and weights estimates accordingly. Macros have been written in GLIM for exploratory graphical data analysis.

Statistical, Mathematical and Computing Methods

Alice Holt Lodge

Work on forming the estimates used in the National Census of Woodlands and Trees has been essentially completed. Further development of work mentioned last year, home range characterization mortality in unthinned crops (*Report 1981*, p.49) has taken place.

Diameter distributions of forest crops have been fitted by a maximum likelihood method using the Weibull distribution. The estimated Weibull parameters were then regressed on mean dbh (diameter at breast height, 1.3 m). The programs are intended for use on different species/treatment combinations in which mean dbh is the main input parameter.

An empirical study of various 'distance methods' for estimating the stocking density of a forest stand and recommendations based on it have been made.

A computer game based on a simple model of growth in a forest stand has been implemented and has aroused some interest in educational establishments for its value to students.

Northern Research Station

It was found that incorporating a second diameter (in addition to dbh) gave estimates of single tree Sitka spruce volumes that were significantly better than those formed using dbh, timber height and mensuration tables.

The statistical problems associated with expressing the effect of a fertiliser application as a reduced rotation length were studied.

Computing with a controlled model of two fully crossed factors with replication, artificial data sets were created and analysed by GENSTAT. The significance of the various possible interactions between components (linear, quadratic, etc.) of the two factors could be adjusted and, in parallel, a series of 3-D computer drawings of the interaction surfaces provided visual insight.

Data Capture and Associated Computing*Alice Holt Lodge*

A program was written for each of two hand-held data terminals (a MSI 88F for Mensuration Section and a Microfin for Work Study Branch) to allow asynchronous communication over public telephone lines. A general review of the station's future use of portable data terminals was instigated and a Datatrak T787 was purchased.

Northern Research Station

In preliminary equipment tests, 11-track analogue tapes from a Racal Geostore logger recording windflow have been digitised with help from the Institute of Geological Sciences.

R. S. HOWELL, D. H. STEWART

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COMMUNICATIONS**RESEARCH INFORMATION****Library**

The book stock was increased by a further 164 books, and subscriptions were taken out for another four journals. The total of loan requests satisfied was again over 10,000 for the year, with 6,135 loans from stock, 788 borrowed from other libraries, and an estimated 3,100 photocopies.

Visitors

The section staff were responsible for the organisation and arrangements for three Open Days held on 2nd, 3rd and 5th July 1981. Attendances were 771 schoolchildren, 1,200 invited guests and 2,500 members of the general public on the three dates respectively.

O.N. BLATCHFORD

PHOTOGRAPHY**Aerial Photography**

Though the summer of 1981 was the worst for some years, flying continued in support of the Census and 80 per cent of the programme was achieved. Extensive maintenance and modification of the aircraft and systems started at the beginning of March 1982. The result of installing a new flight control system, camera mount and drift sight will be reported on at a later date.

Photographic and Illustrator Service

Much of the Illustrator's time was taken up in work for publications. A limited photographic service continued to be available and a considerable effort, photographic and illustrative, went into supplying material for the Open Days held during the year.

I. A. ANDERSON

PUBLICATIONS

Despite the tragic loss of the Publications Officer, Mr K W Wilson, who died half way through the year, the following titles were published:-

Report

Report on Forest Research, 1981 (£5.40)

Booklets

- No.47 Investment Appraisal in Forestry, by R J N Busby and A J Grayson (£3.75).
No.48 Yield Models for Forest Management. Text by P N Edwards (£1.20), models prepared by J M Christie (10p each; binder £1.50, index cards £3.00).

Forest Record

No.103 Badgers in Woodlands (Revision), by E. Neal (80p).

Leaflets

- No.12 Taxation of Woodlands (Revision) (60p).
No.79 Decay Fungi in Conifers, by B J W Greig (£1.30).

Occasional Papers

- No.11 Aerial Application of Insecticide against Pine Beauty Moth. Edited by A V Holden and D. Bevan (£2.50).
No.12 Spatial Analysis of Forest Growth, by P H Nicholls (£5.00).

Arboricultural Leaflets

- No.7 Removal of Tree Stumps, by K W Wilson (£2.00).
No.8 Phytophthora Diseases of Trees and Shrubs, by R G Strouts (£2.40).
No.9 Verticillium Wilt, by G D Pearce and J N Gibbs (£1.35).

Guides

Hazel Coppice at Westonbirt, by J E J White (20p).

Explore the New Forest (Reprint). Edited by D. Small (£3.20).

Special mention must be made of Booklet 48 – Yield Models for Forest Management. This publication is divided into four parts:– a loose-leaf binder; a set of 20 index cards with the general yield class and production class curves of one species printed on each card; a 32-page booklet, and 162 yield models. The models, which cover a range of thinning treatments and spacings for the major tree species, can be purchased separately so that practising foresters can obtain the models relating to their particular crops.

O.N. BLATCHFORD

WOOD UTILISATION

In the joint project with the Electricity Council on spruce power transmission poles (*Report* 1981, p. 52), considerable advances were made in obtaining satisfactory impregnation with wood preservatives. It was recorded that when freshly felled spruce was treated with a water-borne preservative by a sap-displacement process, complete penetration of the sapwood was achieved. The procedure is to attach suction caps to the butts of poles within a pressure treatment cylinder, and to draw off the sap as copper-chrome-arsenate preservative is forced into the wood.

The effectiveness of the system depends primarily upon the proportion of sapwood. The heartwood is quite impermeable. In Norway spruce, where the band of sapwood normally exceeds one third of the radius, the specified net dry salt retention is readily attained. However, in Sitka spruce the radial width of sapwood is sometimes less than 10 mm in which case acceptable retention is impossible (Plate 1). Selection in the forest is therefore essential to ensure that only poles with an adequate amount of sapwood are dispatched for treatment. Additionally the process was successfully applied to Corsican pine medium category poles as a means of overcoming problems of possible deterioration and extended stock holding resulting from the slow rate of air drying in this species.

This method has two salient benefits: firstly, barking and pole-trimming are undertaken as one operation in the pole depot, obviating the need for manual barking in the forest; and secondly, because seasoning is not required before preservation, the treatment cycle is reduced by several months – for instance, poles which were felled in the Forest of Dean during May went into service in Sussex in September. The main disadvantage concerns the need for “hot-logging” to ensure that poles are treated within a few days of felling.

In parallel experiments referred to in earlier reports attempts are being made to improve permeability through bacterial activity induced by immersion in water. Poles placed in ponds in the Forest of Dean, Dyfnant and Drummond Hill during the previous year were removed in September to facilitate drying prior to pressure treatment with copper-chrome-arsenate. Poles from earlier water-treatment trials, which were creosoted under pressure, were put into service in Northern Ireland.

J.R. AARON

OTHER HEADQUARTER DIVISIONS

PLANNING AND ECONOMICS**Monitoring Trends in Recreation**

Reports continue to be received from various parts of the country concerning the numbers of visitors to Commission forests. These reports include traffic counter recordings, records of use of forest drives and of visits to visitor centres. The annual totals for any one site tend to be erratic because of weather fluctuations. It is found that the rise in visits to forests considered likely a decade or so ago has not materialised. The estimate of numbers of visits to our forests made in 1977, namely 24 million, remains the best indicator of the current annual use of Commission forests for recreation.

R.Q. OAKES

Premature Felling in Anticipation of Windthrow

A review of existing guidelines on allowance for windthrow risk in felling decisions has been carried out. The object was to devise a simple and robust method of calculating optimal felling age in the presence of windthrow risk as a practical aid to managers. This was achieved by testing several simple approximate methods against results derived from a more elaborate and realistic model of the distribution of windthrow risk over time. The method chosen, when applied to representative test data, gave critical windthrow probabilities differing from more accurate estimates by much less than the reasonable margin of error in assessment of actual windthrow risk. Revised guides will be issued in due course.

A.J. MOON

PART II

Work done for the Forestry Commission by Other Agencies

FOREST SOILS

NUTRITION AND FOREST SOILS

By H. G. MILLER

The Macaulay Institute for Soil Research, Aberdeen

Much of the past decade has been taken up with a study of the relation between the cycle of nutrients and tree growth in early thinning-stage Sitka spruce (Miller and Williams, 1973). Field measurements and a sample collection were finally completed during April 1981 with the sampling of the sixth experiment in the series, that at Kilmichael forest (Strathclyde). Processing of the large amount of accumulated data is still at an early stage, and many samples have yet to be analysed.

Although not part of the original objective, an interest in the interaction of trees with acid rain has developed during the course of this study. An investigation was facilitated by the geographical spread of the six experimental sites, ranging from the relatively unpolluted west coast (rainfall pH *ca.* 4.7) to the more polluted east coast of Scotland (rainfall pH *ca.* 4.1). The spruce crowns are found to have a striking effect on the acidity of rainwater passing through them, either adding or removing considerable quantities of hydrogen ions. The extent of this buffering depends on the acidity of the incident precipitation, so that in the west the throughfall is consistently less acid than that of the rain, whereas in the east there is evidence that, particularly in late winter, the reverse may be true. An effect of season has also been noted in east coast forest stands on a range of other species, including Scots pine and larch.

Processing of the results from an earlier study of nutrient cycling in Corsican pine continues, a recent development being the appointment of a NERC/CASE postgraduate student to develop a simulation model of nitrogen cycling in pine. Examination of the results from this study, in conjunction with the preliminary data becoming available from the new investigation in spruce, has emphasised the extent to which nutrient demands change with the development stage of a forest stand. Maximum demand upon the soil occurs very early, at the time the green crown is being constructed. Thereafter, the establishment of fully charged nutrient cycles, both within the tree (primarily nutrients recovered from leaves before abscission) and through leaf fall and crown leaching, leads to considerable reductions in the demands made by the tree on soil reserves (Miller, 1981a). The significance of this, and other new areas of knowledge, for forest fertilization practice has been discussed in a recent publication (Miller 1981b).

New experimental data has also been used to show that the concentration of nitrogen in foliage of Corsican pine associated with optimum growth shows

a progressive change with age (Miller, Miller and Cooper, 1981). This value declines linearly with the logarithm of the weight of the plant from 3.3 per cent in young seedlings to 1.4 per cent in trees approximately 2.5 m tall. There is then a gap in the available data, but once the trees have fully closed canopy the optimum nitrogen concentration is found to have risen to 2.0 per cent. The reasons for this pattern of change have not been established, but are thought to be a function of changes in the sink-source relations for nitrogen within the tree as it ages.

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EFFECT OF HEAVY METALS ON SOUTH WALES FORESTS

By K.W. BURTON and E. MORGAN

Department of Science, The Polytechnic of Wales, Pontypridd

Foliar sampling and soil analysis have been carried out to gain a picture of the site factors relating to heavy metal contamination. This work is being extended to include up to 10 sites where Sitka spruce is grown in order to explore the relationship between site factors and growth. Foliar analysis in particular will be of interest since tissue concentrations of metals found at the sites sampled so far approach or exceed those which can be expected to have some effect on tree growth.

Experiments in the laboratory involving uptake from solutions have been carried out to examine the types of effect caused by heavy metals, and the tissue concentrations above which these effects will appear. These critical tissue concentrations have been determined for copper, cadmium and nickel but not for zinc. Synergistic effects of heavy metals are being examined at present by means of a factorial experiment with copper, cadmium and nickel, each at three concentrations.

Experiments in the greenhouse, where seedlings are grown in peat with added cadmium, copper and lead, are being carried out to examine the effect of these heavy metals not only on the plants, but also on the soil microflora and nutrient cycles in which they are involved.

Experiments to examine the interactions between root exudates and heavy metals have been considered. Alterations of the pattern of exudation may affect the amounts of nutrients available due to disruption of mycorrhizal symbiosis. It is hoped that some methods of analysis will make it possible to measure amino acids exuded from seedling roots in the presence and absence of heavy metals.

This work is supported by the award of a SRC/CASE studentship (Forestry Commission/Polytechnic of Wales) to this project.

HYDROLOGY

EFFECT OF UPLAND AFFORESTATION ON WATER RESOURCES

By J.R. BLACKIE

Institute of Hydrology, Crowmarsh Gifford, Wallingford, Oxon

The hydrological effects of plantation forestry have been a major component of the Institute's programme since its formation in the mid-1960s. From catchment studies on Plynlimon and elsewhere, and from detailed studies of the rainfall interception and forest evaporation processes, it has become possible to quantify on a much firmer basis the changes in water use and in streamflow when upland grassland areas are afforested.

In response to queries raised by both forestry and water resources interests the Institute has recently extended its work to cover additional aspects of forest hydrology. A feature of the extension has been the active co-operation of a wide range of interests, both in programme funding and in fieldwork, thus ensuring efficient utilisation of limited funding and research resources. The two major areas in which studies are being extended are:

- (1) Investigation of the applicability of existing results concerning the effects of forestry on streamflow in regions ranging from upland Wales to Thetford and to the very different soils, climate, vegetation and topography of the Scottish Highlands.
- (2) Investigation of the effects of such forest management practices as initial planting, remedial fertiliser application and clear felling on stream water quality.

Forestry and Streamflow

A project covering (1) above was formally initiated in Scotland in 1981 with inter-departmental funding and active support from the Forestry Commission, Department of the Environment, Scottish Development Department, Water Research Centre (representing Scottish water resources interests), Department of Energy, North of Scotland Hydroelectric Board and British

Waterways Board. The project consists of a series of short term studies of component hydrological processes and a longer term experimental catchment study in the Balquhider area of West Perthshire.

Forestry and Water Quality

Traditionally upland water supplies have been regarded as being of very high quality requiring the minimum of treatment prior to distribution to the consumer. Intensification of upland land use, whether it be through grassland improvement or forestry, raises the possibility of some deterioration in this quality. Discussions with forestry, water supply and upland farming interests identified four aspects of upland management which should be investigated in this context: upland grassland improvement and the initial planting, remedial fertiliser application and clear felling phases of forestry. A project has been agreed in which paired small catchments at Glenorchy Forest will be studied to identify the magnitude and duration of any changes in nutrient and sediment concentrations and loadings as a result of these management practices.

HERBICIDES

HERBICIDE EVALUATION FOR FORESTRY USES

By I.D. CLIPSHAM and W.G. RICHARDSON

*Agricultural Research Council Weed Research Organization, Begbroke Hill,
Yarnton, Oxford*

Rhododendron ponticum

Preliminary results of research with hexazinone (Velpar L) and our oil-surfactant blend, mixture 'PB', have been reported previously (Turner *et al.*, 1981). This programme has now assumed much greater importance, being assisted by the provision of ¹⁴C-labelled hexazinone, kindly donated by Dupont (UK) Ltd.

Early work with this radioactive material showed that penetration of hexazinone into *Rhododendron* leaves is greatly enhanced by the addition of 10 per cent v/v of Mixture 'PB'. When the tracer was applied as individual drops in a 3 per cent v/v solution of Velpar L without 'PB' to the leaf surface, no significant entry of labelled compound into the leaf tissue occurred over 48 hours. However, with 10 per cent 'PB' in the treatment solution, 45 per cent of the labelled compound had penetrated the leaf tissue after only 6 hours. Penetration rose to over 80 per cent after 48 hours. No significant translocation of the labelled material from the treatment area was observed over this period.

Initial studies of spray retention by leaves suggested that although there was no difference in the amount of spray liquid retained by the plant following application at the rate of 250 l/ha, addition of mixture 'PB' caused up to 35 per cent of the intercepted spray to run down the leaf petioles to the buds in the leaf axils and onto the main stem (Plates 2a, b; 3a, b). This, as well as increasing herbicide penetration, may have a bearing on the increased phytotoxicity observed in pot experiments in previous years.

Pot Experiments for Weed Control in Young Plantations

Cyprazine, which selectively controls heather (*Calluna vulgaris*) growing amongst spruce plantings, may unfortunately not become commercially available. Other new herbicides recently tested which show promise for this purpose include Dowco 433, triclopyr and glufosinate (Hoe 39866). Unfortunately, this latter herbicide injures spruce so can only be used for heather control pre-planting. However, Dowco 433 and triclopyr both controlled *C. vulgaris* at a rate of 2 kg ai/ha and were tolerated by spruce and other important conifer species, except Japanese larch which was damaged by triclopyr.

Several new grass killing herbicides are now available. One, Sethoxydim (NP55) gave good control of both *Calamagrostis epigejos* and *Deschampsia caespitosa* at 2 kg ai/ha. As in previous years the addition of 5 per cent actipron to atrazine treatments improved performances. Summer applications of propyzamide were not as effective as in previous years, but appeared worthy of further investigation. Hexazinone controlled *Holcus mollis*, *Molinia caerulea*, *Deschampsia caespitosa*, *Calamagrostis epigejos* and *Pteridium equilinum* at 1 kg ai/ha. The pines and spruces were tolerant of 2 kg ai/ha. September treatments were, in general, not as good as those in April and July.

Applications of glyphosate in reduced spray volumes (<100 l/ha) did not affect activity, but late (Sept./Oct.) applications were more effective on grass species than earlier treatments. Addition of extra surfactants improved performance on some weed species without adversely affecting crop tolerance. These are interim results based on visual scores made two months after treatment, more detailed results will be available later in 1982.

Weed Control in Seed Beds

Mixtures of oxyfluorfen and napropamide were examined for weed control ability in conifers, and showed considerable promise. However, the use of the safener naphthalic anhydride as a seed dressing did not improve tolerance of Sitka spruce, Lodgepole pine, Douglas fir, Japanese larch, birch or sycamore to any herbicide tested.

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TREE PHYSIOLOGY

RAPID VEGETATIVE PROPAGATION OF SILVER BIRCH
AND SCOTS PINE BY TISSUE CULTURE

By A.D. CAMERON and J.D. MATTHEWS

*Department of Forestry, University of Aberdeen**Silver Birch Cuttings*

Batches of cuttings were taken each month throughout one year, starting May 1981, from source plants in their first and fourth years of growth, then placed under favourable rooting conditions to suit type of cutting.

The treatments used were size (one internode and three internodes), cold storage (none and one week at 2°C) and presence or absence of a commercial auxin dip (Murphy Hormone Rooting Powder, Murphy Chemical Ltd.). Highest successful rooting (90 per cent) and speed of rooting (about 15 days) were obtained from cuttings taken in May and June and derived from plants in their first year of growth. The treatments applied had no effect on the rooting and survival (consistently 90 per cent) of these cuttings. Larger cuttings rooted more quickly than the small, single-internode cuttings, but the economy in material of the small cuttings may be more important. The auxin dip doubled the number of roots per cutting but did not speed up the process of rooting or affect rooting percentage and survival of cuttings.

Scots Pine Cuttings

Batches of cuttings taken at monthly intervals throughout one year, starting May 1981, from pine seedlings in their first year of growth were subjected to cold storage (none and one week) and the presence or absence of an auxin dip (Murphy Hormone Rooting Powder). Cuttings were rooted under favourable conditions of intermittent mist, basal heating and long days. High rooting success of over 90 per cent was obtained in all months except July where it was below 70 per cent. A very high survival rate of rooted cuttings, often 100 per cent was attained. On average, cuttings required 30 to 40 days to root, with the exception of November cuttings which averaged 52 days. The effect of an auxin dip consistently increased number of roots in comparison with untreated cuttings and this may justify its use.

Silver Birch Tissue Culture

Five auxins, indole-3-acetic acid (IAA), indole-3-butyric acid (IBA), naphthaleneacetic acid (NAA), *p*-chlorophenoxyacetic acid (*p*CPA) and 2,4-dichlorophenoxyacetic acid (2,4-D), and two cytokinins, 6-furfurylaminopurine (kinetin) and 6-benzylaminopurine (BAP) were investigated in various combinations and at various concentrations for their effect on callus development and subsequent morphogenesis on birch stem internodes. All five auxins induced satisfactory callus development and the presence of a cytokinin significantly enhanced this development. Only IBA, NAA and *p*CPA were further investigated in combination with the two cytokinins for the morphogenetic potential. Of the two cytokinins, BAP enhanced greater

callus development in comparison with kinetin and it also increased shoot formation. The best auxin in association with BAP was NAA. Cultures with IBA and ρ CPA induced fewer shoots, and chromosome counts in plantlets derived from ρ CPA cultures revealed a high level of polyploidy. The best combination of NAA and BAP induced more than one hundred shoots (over two harvests) from each piece of callus. Shoots were best rooted under intermittent mist in a peat and sand medium; this gave more than 90 per cent rooting and plantlet survival was very high.

Scots Pine Embryo Culture

Embryos were excised under aseptic conditions and inserted upright into a medium containing NAA and BAP. Several concentrations of the hormone mixture were investigated. Numerous buds formed on cultures containing relatively high levels of BAP and low levels of NAA. These buds were induced to extend by transferring them onto a medium containing no growth substances. The resulting short shoots were isolated and placed on a similar medium to encourage further growth. When these shoots were approximately one centimetre in length they were transferred to the greenhouse and rooted like normal pine cuttings under intermittent mist. Rooting and survival were over 90 per cent.

FOREST ZOOLOGY

LONG-HAIRED FALLOW DEER

By R. H. SMITH and ELIZABETH JOHNSON

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Inheritance

The genetic study has continued in enclosures in Mortimer Forest (Salop) and the New Forest (Hampshire). Table 4 shows the phenotypes of the offspring produced in summer 1981 in the Mortimer Forest enclosures, together with their identifying code numbers.

TABLE 4
PHENOTYPES OF FALLOW DEER OFFSPRING (1981)

Enclosure	Buck	Doe	Fawn	Inbreeding Coefficient
1-2	L22 Short	L14 Short L24 Short L26 Short L30 Short	L38 Short L35 Short L37 Short L36 Short	0.25 0 0.375 0
Whitcliffe	L27 Long	L1 Long	L39 Long	0

The short-haired doe L16 was mated with the buck L22 in enclosures 1 and 2 but produced no fawn.

In the New Forest enclosure, the long-haired buck L9 was again mated with three short-haired New Forest does in autumn 1980. Three fawns were born in summer 1981, but at the catch-up in autumn 1981 only two of the three mature does and one of the three fawns were alive. Remains of the mature doe and two fawns were found. Examination of the tooth growth rings of the dead doe by M. Roe (Wildlife Management Branch, Alice Holt Lodge) indicated that the dead doe was fourteen years old. A second mature doe died during the very cold weather in January 1982. All of the deer in enclosures in Mortimer Forest survived the 1981 summer and the 1981–82 winter.

Inbreeding

Inbreeding is normally thought of as detrimental and has been related to juvenile mortality of ungulates in zoos (Ralls *et al.*, 1979). Some deliberate inbreeding has been introduced into the Mortimer Forest pedigrees while other crosses have used unrelated parents, as shown in Table 4; for example, L26 is the daughter of L22, and L14 is the mother of both L22 and L26 (Smith and Johnson, 1979, 1980). Although the sample size is small, there is no evidence of inbreeding depression. In fact, the one cross that did not produce a fawn in 1981 was between unrelated parents (L16 x L22). The results so far support the suggestion of Smith (1980) that genetic bottlenecks in the history of British fallow deer may have eliminated the deleterious, recessive alleles which are normally responsible for inbreeding depression.

Physiology

The detailed characteristics of age and seasonal coat changes in long-haired and short-haired fallow deer have now been published (Johnson and Hornby, 1980). It still remains important to investigate the metabolic requirements of long-haired compared with short-haired fallow deer when facilities become available (Smith and Johnson, 1979).

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SOCIAL ORGANISATION AND ECOLOGY OF
SIKA DEER

By R. J. PUTMAN and J. C. E. MANN

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This project nears completion and appears to have been very successful. The extensive programme of fieldwork reported here last year (Putman and Mann, 1981) was terminated at Christmas 1981. Monthly clipping of vegetation ceased at the same time, and nutrient analysis of these samples is now complete. Details from these will, it is hoped, provide some explanations for the observed seasonal and monthly changes in diet.

Collections of rumina over three years from Wareham (a coniferous forest) and four from the New Forest (mainly deciduous) have been analysed to yield details of the winter diet of the sika. Previous work (Horwood, 1971) has suggested marked differences in feeding strategy with the Wareham animals being mainly grazers, and the New Forest ones mainly browsers. This idea has been validated in winter, but faecal analysis (used to clarify diet outside the culling season) has shown that the New Forest animals are as much, if not more, grazers than the Wareham ones in the height of summer. The Wareham sika also have a heavy dependence upon *Calluna* (present in superabundance) and their seasonal diets are very similar, whereas in the New Forest sika the diet shows marked seasonal changes. Of further interest is the close similarity between the winter diet of Wareham and Scottish sika. Of economic interest is the fact that New Forest deer take a considerable amount of coniferous browse in the diet throughout the year, but the Wareham and Scottish animals hardly exploit this resource at all.

Analysis of data collected from driven transects carried out over the full twenty four hour period at Purbeck and in the New Forest continues; details of seasonal and diurnal patterns of habitat use, and of activity rhythms, are now available. The traditional dawn and dusk activity peaks reported previously (Putman and Mann, 1981) are found at both study sites, but shifts in the diurnal patterns of habitat use are more complicated in the finer-grained environment of the New Forest. Extensive use is made here of pre-thicket and thicket areas in the summer, with use of the mixed woodland mostly confined to the night. In the winter the pre-thicket areas are hardly used at all, the main emphasis falling on the polestage woodland and the rides. Forestry activities, creating supplies of brash, provide food which is used extensively until the supply is depleted, and then the areas are avoided.

At Purbeck the animals move out into open areas (fields, heathlands, and saltmarsh) to feed under the cover of darkness, frequently forming feeding aggregations of twenty or more individuals, but are almost impossible to find in the plantations during the daytime. This is a pattern that hardly varies throughout the year and which clearly results in the seasonally unchanging diet.

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INDIVIDUAL QUALITY AND DISPERSAL IN THE GREY SQUIRREL

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Experimental removal trap grids were used to monitor grey squirrel dispersal in Wytham Woods, (Oxfordshire), during summer 1981. This was an extension of the work described by Don (1981). The information has enabled a more detailed comparison of qualitative characteristics to be made between animals classed as dispersers and those classed as residents. Unlike summer 1980, the peak period of dispersal in June 1981 revealed no significant preponderance of males.

An analysis of the age structure of the dispersing squirrels was possible by use of the eye lens ageing technique. This revealed that, as during summer 1980, younger cohorts predominated within the disperser group. In particular, there were significantly more young of the previous year's spring and summer litters amongst dispersers than expected, if the probability of resident squirrels dispersing was independent of age. In the summers of both 1980 and 1981, within comparable sex and age groups, dispersers did not appear to differ from residents in their sexual condition or overall body condition. The summer dispersal rate was calculated for all three years of the study and compared to the demography of resident squirrels. No obvious relationships were found.

In order to relate dispersal to the dynamics of space-use in resident squirrels, an analysis of home ranges was carried out. The data for this work was obtained from capture-mark-release records over the period 1978 to 1981. Since bias may occur from using traps as a means of locating individuals, comparisons were made with data collected by radiotelemetry. The results suggested that the major limitation of trap-data based range estimates was size of sample. By adopting analytical procedures which overcome individual sample size limitations, useful range estimates were obtained from trap data. This analysis revealed an increase in the size of non-juvenile male home ranges during each summer (1979–1981), compared to those of non-juvenile females.

The demographic information from a high density and a low density squirrel population was analysed for the period 1979 to 1980. The two populations occurred in different habitat types, separated by over one mile. Despite differences in mean absolute densities, the reproductive patterns were generally similar in the two areas each year. Survivorship patterns

differed between years, but showed no clear relationship with density, estimated food availability or habitat type.

The work reported above was concluded in 1981.

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BEHAVIOUR OF RARE REPTILES IN RELATION TO FOREST MANAGEMENT

By I. F. SPELLERBERG and S. WRIGHT

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Increasingly the Sand lizard (*Lacerta agilis*) is becoming restricted to “managed” areas where it is protected from the pressures of habitat change, disturbance, etc. However, populations of this and other rare vertebrates continue to survive within forest plantations and there seems to be every possibility of conserving these species in well-managed forests.

Unlike other developments, such as urbanisation, the establishment of a forest plantation does not completely remove all heath thereabouts. Heath remains in two distinct situations: open areas, including specific conservation sites and areas unsuitable for forestry, and “temporally limited” habitats, i.e. the vegetation along ride edges and under plantations. Although, because of the presence of a growing crop, the local environment of these latter sites will only be available for a limited period, it represents a large area of potential habitat. The aim of this project is to look at how the use of such habitats by lizards can be optimised. There are two main questions to be answered: firstly, which of the habitats within the full range from bog to dry heath can be used and what influence are the trees having; and secondly, how much are the animals ranging through these habitats and what is their ability to colonise new areas as they become available?

The two main types of habitat, namely along rides and that under growing crops, are being looked at differently. Ride habitat is being assessed by regular searches of the ride-edge vegetation to identify those areas where lizards are found. In this way it is hoped to produce accurate seasonal maps of lizard distribution along rides. This distribution can then be used to pinpoint general kinds of habitat which the lizards are using. These may be identified by two main factors, namely the amount of sunshine which an area is receiving and the type of vegetation. This information will also be applicable to the habitat being used within a growing crop, but here, closer comparison is being made of the habitat around lizard sightings with that around random points in the same area.

Lizard movement can be assessed on a daily and a seasonal basis. Data on seasonal movements are being collected in conjunction with the above work on

habitat, by identifying and pinpointing the position of as many animals as possible. For information on daily movements a system of radio-tracking is being developed. Individual animals are being tracked for seven day periods, during which time they are located about five times a day. This will enable an accurate home range to be drawn up, and will show how home range is related to habitat and how it changes with the season.

FOREST ENTOMOLOGY

CONTROL OF POLYMORPHISM IN THE GREEN SPRUCE APHID,

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Morph Determination

The effect of tree phenology, aphid density, photoperiod and temperature on the induction of alate (winged) *Elatobium abietinum* has been studied (Fisher, 1981), and all but temperature have been found to be important. Alate production was compared contemporaneously on dormant (January stage), natural (May stage) and advanced (late June stage) Sitka spruce subjected to an increase in photoperiod. Alate production comparable with the regular spring peak (Carter and Cole, 1977) was found only in aphids transferred from 10.5 to 16 hours photoperiod; there was a significantly lower proportion of alatae on the advanced trees (Table 5). *E. abietinum* was subjected to the same photoperiod increase in the autumn (when alatae rarely occur) and only 8 per cent became alatae. Crowding of the aphids was found

TABLE 5

PROPORTIONS OF ALATE *ELATOBIMUM ABIETINUM* PRODUCED ON THREE PHENOLOGICALLY DIFFERENT STAGES OF SITKA SPRUCE WHEN TESTED UNDER CONTROLLED CONDITIONS IN MAY WITH AND WITHOUT A PHOTOPERIOD INCREASE (TOTAL APHID NUMBERS IN BRACKETS)

	Dormant Trees (Jan. stage)	Natural Trees (May stage)	Advanced Trees (June stage)
Constant 10.5 hours photoperiod	—	1% (93)	—
Photoperiod transfer of 10.5 to 16 hours	83% (87)	76% (70)	46% (97)

to increase the proportion of alatae by 27 per cent but only at the time of the spring peak.

The requirements for alate production are an increasing photoperiod and a nutritionally suitable host tree. Aphid density acts as a modifier of the response. Experiments are being conducted to determine whether photoperiod is acting directly on the aphid, or indirectly via the tree.

Studies on the Quality of Infested Foliage

E. abietinum has a higher mean relative growth rate (MRGR) on previously infested than on previously uninfested Sitka spruce (Fisher, 1981). An amino acid analysis of infested compared with uninfested foliage revealed that out of 18 amino acids tested six essential ones increased, and one essential and one non-essential amino acid decreased. This may explain the improved aphid MRGR on infested foliage. The response of the plant tissues to the physical penetration by the aphid's stylet and to the aphid's saliva is being explored.

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LOW LEVEL UTILISATION OF BREEDING MATERIAL BY ELM BARK BEETLES IN NORTH WEST ENGLAND

By D. P. O'CALLAGHAN

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The killing of an elm by Dutch elm disease provides potential breeding material for the large and small elm bark beetles (*Scolytus scolytus* and *S. multistriatus*) that spread the disease. In southern Britain large increases in bark beetle populations have occurred in affected areas and as a consequence disease spread has been very rapid. During the course of experiments on the feasibility of using the pheromone-baited trap tree technique (O'Callaghan, Gallagher and Lanier, 1980) to control the elm bark beetle population on Merseyside, it became apparent that the beetle population was very much smaller than would have been expected, given the high number of dead elm trees standing throughout the county.

To assess the situation more fully, dead elms in Liverpool and Southport, Merseyside, were examined for the presence of bark beetle galleries. The inner bark was exposed with a hatchet or knife at the four cardinal points on the main bole and up to a height of 3 m from the ground. Trees which still

possessed live (cream-coloured) inner bark were not considered further. Trees with dead (brown) inner bark were assigned to four categories on the following basis: (1) no larval galleries; (2) less than 40 per cent of the inner bark occupied by larval galleries; (3) between 40 and 90 per cent of the inner bark occupied by larval galleries; (4) more than 90 per cent of the inner bark with larval galleries ('brood trees'). The results of the survey expressed separately for Wheatley elm (*Ulmus carpinifolia* var *sarniensis*) and wych elm (*U. glabra*) are contained in Table 6. On average, only 19 per cent of the lower boles had been fully utilised by bark beetles and over 50 per cent had no beetle galleries at all.

At Liverpool the Wheatley elm were examined in 1980 and the wych elm in 1981, so no comparison between the two elms could be made. However, at Southport, where all the data were collected in 1980, there was an indication that the bark beetles had been more successful in utilising the boles of Wheatley than of wych elms. Thus of the Wheatley elms, 38 per cent were brood trees and 31 per cent had no galleries, while of the wych elm the equivalent figures were 9 per cent and 56 per cent.

TABLE 6

THE UTILIZATION OF ELM BARK BY ELM BARK BEETLES IN MERSEYSIDE COUNTY

Population	Category				Total
	1	2	3	4	
LIVERPOOL					
	Number of trees sampled, with dead inner bark				
Wheatley Elm	60	17	17	22	116
Wych Elm	54	10	11	15	90
SOUTHPORT					
Wheatley Elm	13	6	7	16	42
Wych Elm	30	11	8	5	54
TOTAL	157	44	43	58	302

(For detail of categories see text)

It has recently been shown by Webber (1981) working on wych elm in mid-Wales that once the inner bark of a diseased elm has been colonised by the pycnidial fungus *Phomopsis oblonga*, it can no longer be utilised by the elm bark beetles for breeding. It seems probable that the data presented here represent the first large scale quantification of the effect of *P. oblonga* on elm bark beetles. Although no mycological examinations were made, zone lines characteristic of *P. oblonga* were observed in the dead bark of most of the trees. In addition detailed studies by Webber and Gibbs (unpublished) have shown that *P. oblonga* is the principal coloniser of the inner bark of dead elms on Merseyside.

The more successful breeding in Wheatley than in wych elm at Southport is interesting. It can perhaps be explained by the fact that when *S. scolytus* is given the choice of fresh logs of Wheatley and wych elm, it shows some preference for the former species (Kirby and Fairhurst, 1981). This might have an important bearing on whether the bark beetles become established before *P. oblonga* colonisation can take place. Equally *P. oblonga* may be adapted to wych elm and this may influence the relative rate at which it colonises the inner bark of the two species.

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BIOLOGY AND DISTRIBUTION OF BARK BEETLE VECTORS OF DUTCH ELM DISEASE IN NORTHERN BRITAIN

By S. G. KIRBY and C. P. FAIRHURST

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In 1981 continued observations were made on the life cycles of *Scolytus scolytus* F. and *S. multistriatus* (Marsh) in logs of three types of elm at sites in north west England and at the Forestry Commission's Northern Research Station, Roslin, Midlothian. This research was supplemented by laboratory colonisation experiments, geographical distribution studies and collaborative work on pheromone trapping and twig crotch feeding.

S. multistriatus has now been recorded from the northern parts of Merseyside and Humberside Counties. Undoubtedly this species occurs further north, but as it rarely breeds successfully in wych elm, it seems unlikely that it plays a major role in the spread of Dutch elm disease in northern England.

S. scolytus is widespread in Britain and work in 1981 confirmed that English and Wheatley elms are colonised more successfully than wych elm. Approximately twice as many galleries are found on the underside or shaded portions of logs as on the top, a feature not normally seen with *S. multistriatus*. Optimum beetle production is achieved when there are 8–10 maternal galleries per 1,000 cm², each complete gallery system occupying 100–125 cm². As this gallery density is often exceeded in the field (up to 24

maternal galleries per 1,000 cm²) it appears that intra-specific competition may be an important mortality factor. For *S. multistriatus* the optimum level has not been ascertained, but the maximum recorded maternal gallery density in north west England has been 8 per 1,000 cm². This contrasts with a figure of 55, found in Devon in 1980.

S. scolytus larvae occasionally produce pupal chambers in the sapwood (Kirby, 1980; Kirby and Fairhurst, 1981). It is now apparent that while such chambers are found in only one out of every ten galleries in Devon, there is an average of one chamber per gallery in north west England and two per gallery in Lothian.

S. laevis has now been officially recorded from the British Isles (Atkins *et al.*, 1981). This species is considered to be a vector of Dutch elm disease in northern Europe (Lekander *et al.*, 1977). The maternal galleries are longer and the numbers of brood per maternal gallery higher than for the other two species of elm bark beetle, and sapwood chambers are formed in the majority of larval galleries. *S. laevis* has now been recorded from Cheshire, Merseyside, Humberside, Durham, Lothian and Strathclyde but its abundance in relation to the other vectors and its life cycle in Britain are not yet known.

A survey in the Isle of Man showed that elm comprises one third of the Island's hardwoods, but the use of pheromone traps and the examination of moribund trees provided no evidence for the presence of elm bark beetles. One record was made of breeding in elm by *Scolytus intricatus*.

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REDUCTION IN PINE SHOOT MOTH POPULATIONS BY ATMOSPHERIC SATURATION WITH PHEROMONE

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The technique of atmospheric permeation with lepidopteran pheromones is currently under evaluation as a potential method for population reduction and control. The method, termed mating inhibition, is based on interference

with the normal mate finding processes of male moths searching for females along their scent plumes. The technique has high potential in forestry where use of conventional insecticides could upset predator prey balance leading to further pest problems.

The technique has been assessed at two sites: Kilvey Hill, a 25 ha amenity site of mainly Lodgepole pine in South Wales and on a 2¼ ha seed orchard of Lodgepole pine at Thetford. Population assessments were made by sampling the characteristic resin tents which enclose the feeding larvae. These were sampled in mid-May and counts made of tents per tree, and larvae, pupae and parasitised insects in collected resin tents. Sampling commenced at Kilvey Hill in 1979 where the overall population was 100,050 larvae/pupae per ha; in 1980 the population was 102,500 per ha. At Thetford in 1980 the population was 26,850 per ha.

Pheromone was applied manually in early June before the adult flight season began. The pheromone (E-9-dodecenyl acetate) was applied at a normal rate of 2g per ha in a hollow fibre formulation (Conrel fibres) designed to give continuous release over the 70 day flight period.

Monitoring of the experiment by assessment of trap catch over the flight period revealed a >96 per cent reduction in trap catch over control areas at both sites. Population assessment in 1981 revealed a population at Kilvey Hill of 36,000 per ha on treated sites and 92,000 per ha on control sites. At Thetford the larval/pupal population was 3,250 per ha on treated plots and 25,000 per ha on control plots. Parasitism had also increased on treated sites (e.g. Kilvey Hill: treated sites 53 per cent, control sites 24 per cent; 1980 20 per cent overall). The sites were re-treated with E-9-DDA in June 1981 for population assessment in 1982.

TIMBER UTILISATION

JOINT RESEARCH PROGRAMME ON BRITISH-GROWN TIMBER

By T. HARDING

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The joint research programme on British-grown timber, supported by the Forestry Commission, has continued at the Princes Risborough Laboratory. To speed the work on the effect of forest management techniques on wood quality, a member of staff of the Forestry Commission has been seconded to the research team at Princes Risborough Laboratory.

The Effect of Spacing on Stress-Graded Yield of Sitka Spruce

The area planted with spruce in Britain is such that, when the forest comes into full production, a large volume of timber will need to be marketed for structural use, because the traditional markets for British softwood will

become saturated. Stress grading studies at Princes Risborough Laboratory have shown that British-grown spruce can give acceptable yields of structural timber provided that it is machine graded. However, these studies were made on timber from trees established 40 or more years ago, planted at 1.4 m spacing and managed according to the practices in vogue in the 1950s and 1960s. Current management practice seeks to reduce costs, for example by wider planting and by eliminating thinning, or to enhance vigour by site improvement. The effect of these changes on machine graded yield needs to be established.

Work carried out over a number of years at Princes Risborough Laboratory has shown that enhanced vigour affects wood characteristics, such as knot size and wood density, which have a direct bearing on the structural performance of timber. Work to quantify the interactive effect of these characteristics on the strength and machine yield is planned. However, to obtain interim guidance a study is in progress to directly examine the effect of planting distance on machine stress graded yield. Some 30 trees have been taken from each of four plots at Clocaenog Forest, North Wales, where Sitka spruce was planted in 1935 at 0.9, 1.4, 1.8 and 2.4 m and thereafter left unthinned. The machine performance of timber from each plot is being studied and the yield of structural-grade timber is being determined. This will provide hitherto unavailable information for use in the economic appraisal of wider spacing.

Conversion of British-Grown Timber

The computer controlled conversion aid developed at the Princes Risborough Laboratory and code-named LOCAS (Laser Optimiser and Cant Alignment System) was first demonstrated to the Scottish sawmilling industry in November 1980. It had been intended to follow this as soon as practicable with a second demonstration for sawmillers in England and Wales. However, in response to comments from the Scottish demonstration it was decided to precede the English/Welsh demonstration with an extended proving trial to confirm that the claimed uplift in yield could be obtained in a working sawmill. The requirements for an extended trial (e.g. uniformity of production, suitable lay-out and timber flow lines, and potential for tallying out-turn) laid constraints which were difficult to meet. Acceptable conditions were found in the sawmill of Lampeter Timber and Trading Co., Lampeter, Dyfed and the management kindly agreed to co-operate in the trial.

A number of modifications to the prototype equipment were required for the more demanding environment of an industrial trial. Stronger lasers, with safety cut-outs, were required for scanning barked logs, and the electronic and computer systems were made more robust. The scanners and computer have now been running in the sawmill in a monitoring mode for six months and, together with a sawn board tallying microcomputer developed at PRL, have been gathering conversion yield data for the "before LOCAS" situation at the sawmill.

A hydraulic cant positioning system has been developed to replace the manual alignment aid demonstrated at Nairn and this is now ready for trial installation. When this is operational the second phase of the trial in which the conversion will be LOCAS controlled will commence.

APPENDIX I

Publications by Forestry Commission Staff

Priced publications issued by the Forestry Commission are available from Her Majesty's Stationery Office at Addresses shown on the back cover.

ATTERSON, J. (1981). The co-ordination of establishment operations. Voluntary paper for the XVII IUFRO World Congress, Japan, 1981.

Co-ordination of establishment operations in forests is necessary for efficiency and economy, as many and varied operations are involved over many years to successfully establish a forest stand. Most operations depend on other operations having been previously carried out, and this paper discusses all establishment operations and their relationships in time with other operations under British conditions of climate, topography and soil.

BIGGIN, P. (1981). Forestry and bracken. In *Proceedings B of the Royal Society of Edinburgh Symposium on Bracken in Scotland*, March 1981.

Bracken grows on sites suitable for forest tree growth allowing a wide choice of tree species. However, the trend in afforestation is towards poorer soils and the area of bracken sites planted is declining. Bracken will damage young trees and methods of its control are reviewed. Hand weeding still has a part to play but most weeding of heavy bracken growth is by herbicides. Experiments on dicamba, chlorthiamid, picloram and more recently on asulam and glyphosate demonstrate a gradual improvement of herbicides in selectivity and in cost effectiveness.

BINNS, W. O. and FOURT, D. F. (1981). Surface working and trees. In *Proceedings of the Conference on the Productivity of Restored Land*, Royal Geographical Society, London, 1981, Land Decade Educational Council, 23-29.

Modern methods of restoration almost always compact the soil. Good slopes provided by ridges 30 m wide with slopes of 1:10 to 1:15 both shed water and allow it to move into the spoils. The ridges themselves should slope lengthways and have drains in the gullies on heavier spoils. Compaction is best relieved by deep cultivation across the ridges with a 300 horse-power crawler tractor and mounted triple tines, preferably winged. Cultivation should only be done in dry weather. Deficiencies of mineral nutrients are uncommon, but nitrogen deficiency is frequent. Nitrogen-fixing plants are increasingly being tried for upgrading raw spoils.

BRASIER, C. M. (1981). Laboratory investigation of *Ceratocystis ulmi*. In *Compendium of Elm Diseases*, eds. Stopes, R. J. and Campana, R. J., Minnesota, American Phytopathological Society, 76-79.

Gives an account of techniques for handling *Ceratocystis ulmi* including obtaining different spore stages of the fungus; preparing selective antibiotic media for the isolation of *C. ulmi*; storage methods for stock cultures; identification of the aggressive strains by growth rate and pathogenicity tests; identification of EAN and NAN races of the aggressive and non-aggressive strain; and the determination of mating type.

BRASIER, C. M., GRIFFIN, M. J. and MADDISON, A. G. (1981). The cocoa black pod Phytophthoras. In *Epidemiology of Phytophthora on cocoa in Nigeria*, eds. Gregory, P. H. and Maddison, A. C. Phytopathological Paper 25, Commonwealth Mycological Institute, 18-30.

Gives an account of the recent discovery of, and the cytological morphological and epidemiological properties of the different cocoa black pod Phytophthora, with special reference to *P. megakarya* sp. nov. and *P. palmivora* in Nigeria.

CARNELL, R. and HINSON, W. H. (1981). Oxygen flux: field measurement using a polarographic recorder. *Journal of Applied Ecology* 18, 537-545.

By automatically scanning a pre-determined voltage range applied to each set of up to 24 platinum microcathodes in turn, the instrument produces a set of polarograms from which a flux-derived current can be unambiguously determined. The robust microcathodes are made of a

hard platinum-iridium alloy cased in resin-impregnated glass fibre, the whole instrument being both rugged and portable. Applied potential and scanning rate can be preselected, usually to -500 mV at 33 mV/min⁻¹. Difficulty in extrapolating transient to steady state diffusion and the uncertainty associated with the exact cathodic processes involved are discussed.

COUTTS, M. P. (1981). Effects of root or shoot exposure before planting on the water relations, growth and survival of Sitka spruce. *Canadian Journal of Forest Research* **11** (3), 703-709.

Seedlings were exposed either by the root or the shoot to drying conditions in a growth room. Changes in leaf water potential and rate of water loss were determined and measurements were made on the moisture content of the shoot, woody root, and fine roots. It was concluded that measurement of neither whole plant moisture content nor leaf water potential prior to planting can show whether a plant has been subjected to damaging conditions. Root exposure of plants in different stages of growth indicated increased sensitivity to exposure the further the plants were removed from dormancy.

COUTTS, M. P. (1981). Effects of waterlogging on water relations of actively-growing and dormant Sitka spruce seedlings. *Annals of Botany* **47**, 747-753.

Actively grown or dormant seedlings were waterlogged in a growth room at 15°C. Shoot and root growth, transpiration and leaf water potential were measured. The stage of activity of the plant at the time of waterlogging made a greater difference to the response in terms of the parameters measured, than differences between tolerant and intolerant species which have been reported in the literature.

COUTTS, M. P. (1981). Leaf water potential and control of water loss in droughted Sitka spruce seedlings. *Journal of Experimental Botany* **32** (131), 1193-1201.

Seedlings were grown in a double chamber with the bulk of the roots in the upper part where they dried out the soil when water was withheld. A few new roots penetrated into the lower part in which the soil remained moist. The double chamber system enabled the plant to attain a high water potential by night and the shoot was only periodically under mild water stress. The behaviour of the stomata appeared to be modified by conditions at the root, and it is proposed that the response to leaf water potential depends on whether the latter is reduced by resistances in the xylem between root and leaf, as is known to occur in large trees in moist soil, or by stresses at the root itself.

COUTTS, M.P. (1981). The tolerance of tree roots to waterlogging. V. Growth of woody roots of Sitka spruce and Lodgepole pine in waterlogged soil. *New Phytologist* **90** (3), 467-477.

Rooted cuttings were grown in such a way that a 37.5 cm length of the woody root on one side of the plant was subjected to waterlogging. The growth and survival of the woody and primary roots are discussed in relation to differences in oxygen transport known to occur in the two species.

EDWARDS, P.N. and CHRISTIE, J.M. (1981). *Yield models for forest management*. Forestry Commission Booklet 48.

This publication is divided into four parts: a loose-leaf binder; a set of index cards with the yield class curves of each species; a 32-page booklet; and a number of yield models, printed on separate sheets. The booklet was written by P.N. Edwards, and it contains sections describing the yield class system, describing yield models and their construction, and explaining how to use yield models. Assortment tables are provided for a range of treatments. The models have mostly been prepared by J.M. Christie, and a range of thinning treatments and spacings is available for the major species.

EVANS, J. [and BROOKER, M.I.H.] (1981). The correct identity of some trees attributed to *Eucalyptus coccifera* in Cornwall, United Kingdom. *Forestry* **54** (2), 211-212.

An impressive stand of eucalypts in Bishop Wood, near Truro, for long considered to be *E. coccifera*, has been correctly identified as a different species of peppermint - *E. nitida*.

EVANS, J. (1981). Eucalypts for firewood – are we up a gum tree? *Y Coedwigwr* 33, 56–63.

The prospects for growing eucalypts in Britain as short rotation firewood crops are considered. Several species (a) are hardy enough to survive average British winters, (b) have a moderate wood density, and (c) produce vigorous coppice. No specific recommendations can yet be made but trials are described.

EVANS, J. (1982). *Plantation forestry in the tropics*. Oxford University Press, 472 pp.

A textbook about tropical plantation forestry describing (a) the increasing importance of tropical plantations and why they are being established, (b) some land, social and economic factors surrounding their development, (c) plantation silviculture in detail, and (d) aspects of agro-forestry, protection forestry and plantation ecology. Within the tropics there are some 16 million ha of plantations, consisting mostly of eucalypts, pines and teak. As well as industrial afforestation, small-scale plantings to meet village and community needs and to control erosion are becoming increasingly important. In time, production from plantations could significantly help to stem exploitation of tropical high forest.

FORESTRY COMMISSION/HOME GROWN TIMBER ADVISORY COMMITTEE (1981). Technical Note 32. GM Forest Scrubcutter. *Forestry and British Timber* 10 (3), 15–16.

FORESTRY COMMISSION/HOME GROWN TIMBER ADVISORY COMMITTEE (1981). Technical Note 33. Spherber Portable Chainsaw Mill. *Forestry and British Timber* 10 (4), 21.

FORESTRY COMMISSION/HOME GROWN TIMBER ADVISORY COMMITTEE (1981). Technical Note 34. Sifer SS 103/B Delimber. *Forestry and British Timber* 10 (5), 23–24.

FORREST, G.I. (1981). Geographical variation in oleoresin-monoterpene composition of *Pinus contorta* from natural stands and planted seed collections. *Biochemical Systematics and Ecology* 9, 97–103.

Geographical variation in monoterpene composition in natural stands in North America was similar to that deduced from analysis of planted origins grown in Britain from seed collected in America. Independence of composition on planting site was further shown by analysis of a number of origins grown in Sweden. The monoterpene data showed populations from north-east British Columbia and the Yukon to be characterized by unusually high variation in the biochemical genotypes encountered, and locally to show evidence of a close genetic relationship with Jack pine.

FORREST, G.I. (1982). Relationship of some European Scots pine populations to native Scottish woodlands based on monoterpene analysis. *Forestry* 55 (1), 19–37.

The chemotypic variation in six continental sources of Scots pine was studied. The two Scandinavian varieties were fairly similar to each other but those from middle and southern Europe differed greatly from them and from each other. The results were compared with the native Scottish woodland data and are discussed in the context of the sequential post-glacial migration into Scotland. It is postulated that the Scottish north-western relict woodlands were derived from southern European sources and the south-western relicts from Scandinavia; the remaining Scottish populations show similarities with middle European sources.

GIBBS, J.N. (1981). European forestry and *Ceratocystis* species. *EPPO Bulletin* 11 (3), 193–197.

Ceratocystis spp. are responsible for some serious tree diseases. Vascular mycosis of oak, oak wilt, Dutch elm disease and canker stain of plane are discussed in the context of the information required by a plant protection organisation concerned with the risks created by specific pathogens.

GREIG, B.J.W. (1981). *Decay fungi in conifers*. Forestry Commission Leaflet 79.

The leaflet is a field guide to the identification of decays in conifers in Britain for both foresters and arboriculturists. For the six most important fungal decays in conifers, notes are given on hosts, occurrence, infection and spread. The fruit bodies and decays are described and illustrated by colour photographs. Shorter descriptions are given of the nine less common decay fungi.

GREIG, B.J.W. (1981). The history of the elm avenues at Blenheim and Dutch elm disease. *Quarterly Journal of Forestry* LXXV (4), 207-214.

The original elm avenues at Blenheim date back to the beginning of the 18th century and the Great Avenue was replanted around 1900. The impact of Dutch elm disease on the avenues was relatively slight up to 1975. However, in the hot, dry summer of 1976, elm bark beetles were able to invade trees weakened by the drought and consequently by the autumn of 1977 virtually the entire avenue had been killed by the disease.

HUGHES, A.J.G. (1981). Elmia Show report. *Forestry and British Timber* 10 (7), 15-16.

A brief report of the 1981 biennial Elmia Forestry Exhibition held in Sweden with details of some of the new technology incorporated in production machines designed for highly mechanised harvesting systems.

HUGHES, A.J.G. (1982). Ergonomics of equipment design and operation in forestry. *Ergonomics* 25 (1), 3-9.

The equipment used in forestry is very largely based on modified agricultural equipment, and even where purpose built equipment is available, the use of forestry equipment is very largely governed by the same legislation as that covering agricultural equipment. Because of the particular requirements for forestry equipment which have to be worked continuously in limiting terrain conditions, the paper shows all aspects of ergonomics are considered in the design and operation of the equipment. The paper covers a range of forestry operations and the design features adopted in harvesting operations are illustrated.

INSLEY, H., BOSWELL, R. C. and GARDINER, J. B. H. (1981). Foliar macronutrients (N, P, K, Ca and Mg) in Lime (*Tilia* spp.). I. Sampling techniques. *Plant and Soil* 61 (3), 377-389.

Sampling and analytical precision over two years were indicated by coefficients of variation which ranged from 5.7 to 14.0 per cent for sampling error and 4.3 to 16.1 per cent for analytical error. Concentration of N, P, and K in the leaves was independent of sampling height. Ca and Mg concentrations, however, decreased with increased height on the crown. Differences in concentration between the bottom and top of the crown were 15 and 19 per cent for Ca and Mg respectively. Nutrient concentrations of samples taken from basal coppice shoots were significantly different from those in the tree crown. Nutrient concentration was independent of aspect.

INSLEY, H., BOSWELL, R. C. and GARDINER, J. B. H. (1981). Foliar macronutrients (N, P, K, Ca and Mg) in Lime (*Tilia* spp.). II. Seasonal variation. *Plant and Soil* 61 (3), 391-401.

Mid-summer leaf sampling from 24 limes over a four year period showed that concentrations of N and P in different years were unrelated. Concentrations of K, Ca and Mg were very highly correlated between years. Foliar sampling of 30 common limes throughout two summers confirmed that for K, Ca and Mg there was good correlation between the concentrations found at given dates in successive seasons. These same samples were also used to show the patterns of within season change in N, P, K, Ca and Mg.

INSLEY, H. (1982). The influence of post planting maintenance on the growth of newly planted broadleaf trees. In *Proceedings of the Conference on Cost Effective Amenity Landscape Management*, eds. Addison, C. H. and Thoday, P. R., Horticultural Education Association, 74-80.

Growth rates of broadleaf trees planted in grass swards were nearly doubled by the use of chemical weeding. Fertilisers were often only effective when combined with weed control and the addition of N to Italian alder, a nitrogen fixing species, was found to reduce, not increase, growth rate because of the increased competition from the sward.

INSLEY, H. (1981). Reducing establishment losses. In *Twenty-first Askham Bryan Horticultural Technical Course Report*, Askham Bryan College of Agriculture and Horticulture, North Yorkshire County Council, 32-38.

Discusses plant condition, planting treatments such as root and shoot pruning, backfill mixtures, use of fertilisers at and after planting, and response to subsequent sward control.

INSLEY, H. (1981). Some effects of plant handling on the dehydration and survival of broadleaved seedlings. In *Proceedings of the Conference on Characterisation of Plant Material*, IUFRO Working Group 31.05-04 Freiburg, Waldbau, 180-191.

Describes two experiments in which broadleaved seedlings were subjected to root exposure and water loss under the uncontrolled conditions of a nursery packing shed. Water loss was mainly from the roots and subsequent survival of seedlings was related to period of exposure but not necessarily to water loss.

INSLEY, H. (1982). The use of container grown broadleaved trees. Techniques No. 41. *Landscape Design* 137, 38-40.

A critical appraisal of the use of container grown stock compared with bare-rooted stock. The results of experiments using Japanese Paperpot, 'Amenity' and 'Rose' pots are discussed. These showed that, although container stock can be produced quickly using heated polythene greenhouses with artificial lighting, in the field growth rates are similar to bare-rooted stock. Container stock can be used to extend the planting season, but the 'out of season' period for bare-root stock is extremely short (June - August) when the plants are handled carefully. Conversely container stock can be more expensive to produce and is very much more expensive to transport and plant than bare-root stock.

LONSDALE, D. and PRATT, J. E. (1981). Some aspects of the growth of beech trees and the incidence of beech bark disease on chalk soils. *Forestry* 54 (2), 183-195.

Growth characteristics and the incidence of beech bark disease were assessed within beech stands, aerial photographs of which showed discrete areas of foliar chlorosis. Chlorosis was mainly confined to distinct soil zones which contained microscopically divided chalk. Compared with the non-chlorotic trees, those trees growing in the chalky soil had smaller mean diameter and had a higher current stocking density. The incidence of the early (insect infestation) phase of beech bark disease was the same on the two soil types, but the second phase (bark necrosis) was more severe on the chalky soil.

McCAVISH, W. J. and INSLEY, H. (1981). Give trees a chance - a look at the safe use of herbicides with broadleaved amenity trees. *GC & HTJ* 189 (17), 26-28.

General principles concerning the action of herbicides are discussed. The use and damage symptoms of the herbicides paraquat, glyphosate, propryzamide, dichlobenil and dichlobenil/dalapon mixtures, atrazine and terbuthylazine are described. Procedures for the calibration of spraying equipment are explained.

McINTOSH, R. and HENMAN, D. W. (1981). Seed fall in the Black Wood of Rannoch. *Scottish Forestry* 35 (4), 249-255.

The degree of seed fall was monitored in two plots in the Black Wood of Rannoch in the period 1958-1962. Seed production was prolific in two out of the five years but virtually absent in the other three. Germination tests showed that on average 51 per cent of the seed collected was capable of producing seedlings. It appears that lack of viable seed is not one of the factors responsible for the lack of regeneration in this native pinewood.

MILLER, K. F. and WALKER, W. (1981). Revolutionary ploughing technique. *Forestry and British Timber* 10 (6), 11.

Describes development of a new plough to create spaced upturned turves or 'dollops' ready for direct planting. The potential benefits are more symmetrical rooting with improved stability, retaining the usual advantages of weed suppression, temperature and aeration at the planting position and site drainage associated with ploughing.

PATCH, D. (1981). Tree staking. *The Garden* 106 (12), 500-503.

A review of staking and tying practices with suggestions for minimising the physical damage to newly planted trees.

PEARCE, M. L. (1981). Coppiced trees as energy crops. In *Proceedings from 1st European Communities' Conference on Energy from Biomass*, Brighton 1980, Applied Science Publishers Ltd., 210–215.

A paper covering a desk study and describing an experimental programme.

PEARCE, M. L., WHITE, J., WEBBER, C. and MACDONALD, J. (1981). *Westonbirt Arboretum Annual Report, 1981*.

A report to the Westonbirt Arboretum Consultative Committee with contributions from the Curator/Botanist, Superintendent and Propagation Forester, highlighting the achievements throughout the year.

PHILLIPS, M. T. T. (1981). Coniferous tree seed harvesting in Britain. *Forestry and British Timber* 10 (5), 8–10.

Emphasises practical aspects of choosing and registering a seed source, estimating the size of cone crops, methods of collecting crops and a list of do's and don'ts for would-be collectors.

[PEARCE, G. D. and] GIBBS, J. N. (1981). *Verticillium wilt of trees and shrubs*. DOE/FC Arboricultural Leaflet 9.

Verticillium wilt, caused by *Verticillium dahliae* is a serious soil-borne disease of young trees of a number of genera. It is most commonly found in the nursery but may occasionally affect established trees. Symptoms involve wilting and browning of the foliage and usually discoloration of the xylem. Sometimes the whole tree dies, sometimes only part of the crown shows dieback. Susceptible genera include *Acer*, *Catalpa*, *Cercis*, *Cotinus*, *Rhus* and *Tilia*. Certain broadleaved genera appear to be very resistant, including *Alnus*, *Betula*, *Carpinus*, *Fagus*, *Populus* and *Plantanus*. Conifers are immune. Control treatments involve sanitation and soil fumigation.

REDFERN, D. B. [and SUTTON, B. C.] (1981). Canker and dieback of *Ulmus glabra* caused by *Plectophomella concentrica* and its relationship to *P. ulmi*. *Transactions of the British Mycological Society* 77 (2), 381–390.

A previously unrecorded canker and dieback disease of *Ulmus glabra* caused by *Plectophomella concentrica* sp. nov. is described. *Plectophomella concentrica* is compared with type material of a similar fungus reported as *Dothiorella ulmi* which causes a disease known as the *Cephalosporium* wilt of elms on *U. americana* in the USA. As a result the name *D. ulmi* is transferred to *Plectophomella*.

RENNOLLS, K. (1981). The costs of tree protection. In *Proceedings of the First International Conference on Applied Modelling and Simulation*, Lyon, Vol. IV, 184–187.

When amenity or forest trees are subject to the threat of damage from animals, two main protection options are available: to use a whole region fence or to protect trees individually. It is argued that basing the choice upon a straightforward comparison of capital costs is unlikely to be adequate for many situations; the "risk costs" of the alternative options have to be included in the calculation. Mathematical models of the alternative means of protection are developed and their expected risk costs determined. A qualitative analysis of these models is then done and the implications on the management decision discussed.

RENNOLLS, K. (1981). The total area of woodland in Berkshire is *The Statistician* 30 (4), 275–287.

This paper considers, in case study form, some of the problems a practical survey statistician might have to face when he attempts to produce an optimal sample size allocation for a complex design using non-standard estimators. In the Census of Woodland, use is made of an auxiliary variable within the conditional predictive approach to obtain optional designs. A post-survey evaluation of these techniques is then done.

SMITH, R. O. (1981). Medium expansion foam as a forest fire fighting agent. *Commonwealth Forestry Review* 60 (3), 226–228.

After successful trials and good results from wildfires, medium expansion foam has become accepted as an operational technique for forest and vegetation fire control. Foam applied as a blanket either onto ground vegetation or into forest canopy permits fast creation of effective visible barriers with minimum water consumption. Water applied as foam is held onto vegetation for an hour or more minimising wastage due to drainage or evaporation. The equipment needed to produce foam is simple requiring virtually no maintenance. The units developed permit instant interchange between plain water and foam. Foam application is most effective direct from a moving unit but where terrain conditions require it may be applied through hoses.

STEVENS, F. R. W. (1981). Beat about the bush. *GC & HTJ* 189 (23), 12.

A discussion on beating to induce or increase fruit production in walnut trees.

STROUTS, R. G. (1981). *Phytophthora diseases of trees and shrubs*. DOE/FC Arboricultural Leaflet 8.

This illustrated leaflet describes the nature, diagnosis and control of *Phytophthora* root rot, the one common Phytophthoran disease of woody plants in Britain, and the less common Bleeding canker (a bark disease mainly of apple and Horse chestnut) and beech seedling blight. Most space is devoted to *Phytophthora* root rot which attacks many plant species of any age, and is often difficult to diagnose. Particular attention is given to its control in nurseries where it can be economically devastating.

TABBUSH, P. M. (1982). Herbicides for grass weeding in the forest. *Forestry and British Timber* 11 (1), 20–22.

A range of herbicides recommended for grass weeding in the forest is reviewed. Rates, dates and methods of application are given for glyphosate, paraquat, propyzamide, Fyduan, atrazine, Herbon Lignum, and hexazinone. Information is presented on the effectiveness and safety aspects of the herbicides together with a comparison of costs. The late summer use of glyphosate using 'Roundup' at 2 litres per hectare is introduced and recommended on the basis of its effectiveness and low cost.

TULEY, G. (1980). *Nothofagus in Britain*. Forestry Commission Forest Record 122.

A new edition of Forest Record 79 covering the species that grow in Britain, seed supply and handling, nursery practice, establishment, production, economics, pests and diseases and timber quality. New seed supplies were obtained in 1976 for *N. procera* (from Chile) and *N. obliqua* (from British stands). Yield tables are given to 50 years for both these species. The net discounted revenue is tabulated for *N. obliqua*, *N. procera*, and other commonly planted species, showing that growing *Nothofagus* is profitable on sites where its mean annual increment exceeds 12–13 m³/ha.

WALKER, C. [and READ, D. J.] eds. (1981). *Mycorrhizal Group Meeting*, University of Sheffield. 30 pp.

This publication contains abstracts of the seventeen papers presented at a meeting of people studying mycorrhizas in the United Kingdom. The meeting was held at the University of Sheffield, 24–25 March 1981.

WEBBER, J. F. (1981). A natural biological control of Dutch elm disease. *Nature* 292 (5822), 449–451.

The fungus *Phomopsis oblonga* is frequently observed as a primary coloniser of elm bark in trees dying of Dutch elm disease, particularly in the elm species *Ulmus glabra*. Field observations and laboratory experiments demonstrated that when *Phomopsis* colonises elm bark, it renders the bark unattractive to breeding Scolytid beetles. Furthermore, if the beetles are forced to breed in such bark, breeding is largely unsuccessful and few beetle progeny develop. Under certain conditions *Phomopsis* can play a significant role in the biological control of Dutch elm disease.

WHITE, J. E. J. (1981). *Hazel coppice at Westonbirt*. Westonbirt Arboretum Leaflet 2.

A history of a traditional system practiced in Silk Wood from the middle ages. Contains details of the ecology, silvicultural management and utilisation, along with current work on reclamation.

WILLSON, A. (1981). The application of soil testing methods to site assessment and tree growth. *Mitteilungen aus der forstlichen Bundesversuchsanstalt, Wien*, **140**, 97–108.

The ability of soil testing methods to assess site characteristics, or estimate available nutrients, depends upon the validity of the analytical techniques and a knowledge of the soil test variation in the field. No relationship between 'extractable' nutrients and tree growth could be established even when nutrient deficiencies were extreme. An intensive systematic sampling scheme indicated that soil variability could not account for the poor relationship. Time-concentration studies suggest that the properties estimated by extraction techniques are not the major source of nutrients in forest soils but are part of a complex series of reversible reactions.

WILSON, K. W. (1981). *Removal of tree stumps*. DOE/FC Arboricultural Leaflet 7.

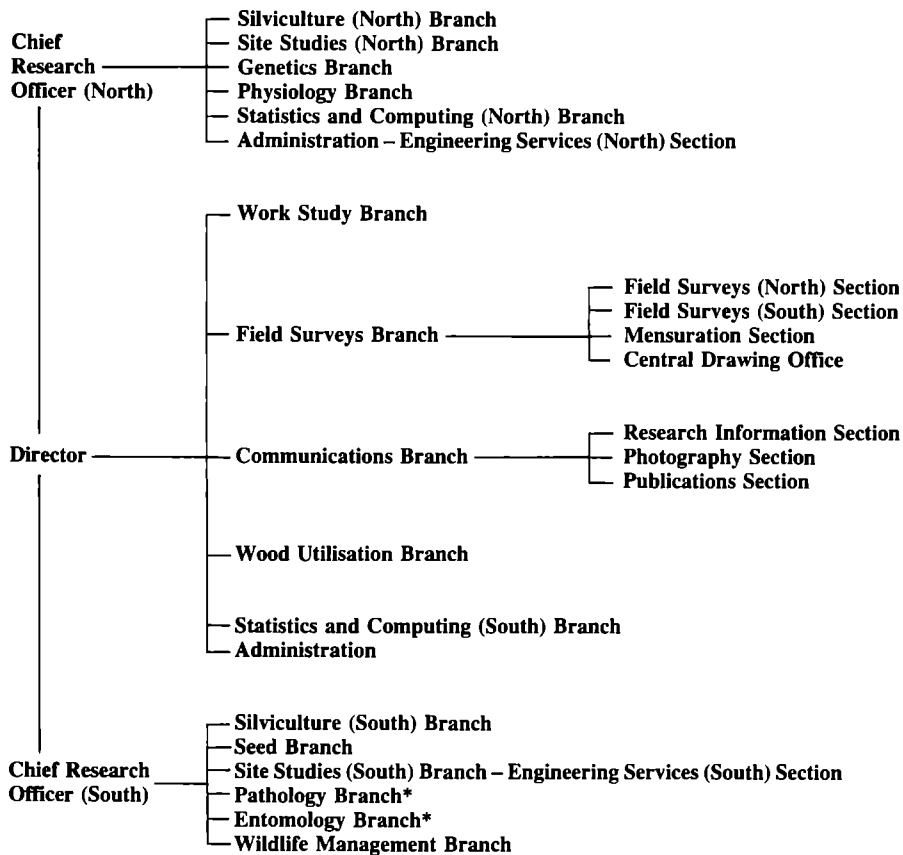
The merits of various methods for the removal of tree stumps are assessed. Techniques of digging, lifting and jacking, winching, chipping, and the use of explosives or chemical treatments, are described and illustrated.

WINTER, T. G. (1981). The larva of *Rhyacionia duplana logaea* Durrant (Lepidoptera : Tortricidae) described and compared with *R. duplana* (Huebner) and *R. simulata* (Heinrich). *Entomologist's Gazette* **32** (4), 233–242.

The history of *Rhyacionia duplana logaea* in Britain and its present distribution in Scotland is given. The larva is described and differences between it and those of *R. duplana duplana* and *R. simulata* from Japan are discussed. The geographic distribution of each is listed and this information is related to their taxonomic status. Further investigation of the relationship between *R. duplana* and *R. duplana logaea* is required in northern Europe.

APPENDIX II

Research and Development Divisional Organisation



*Branches with sections at the Northern Research Station.

APPENDIX III

Staff Engaged in Research and Development

As at 31st March 1982

The main centres for research and development are:

FORESTRY COMMISSION RESEARCH STATION

Alice Holt Lodge
Wrecclesham

Farnham, Surrey GU10 4LH. Tel. Bentley (Hants) 22255 (STD Code 0420)

FORESTRY COMMISSION NORTHERN RESEARCH STATION

Roslin

Midlothian EH25 9SY

Scotland. Tel. 031-445 2176

Some staff engaged in research and development are also stationed at:

FORESTRY COMMISSION HEADQUARTERS

231 Corstorphine Road

Edinburgh EH12 7AT. Tel. 031-334 0303

Research on timber and other forest products is not carried out by the Forestry Commission but by the Princes Risborough Laboratory of the Department of the Environment's Building Research Establishment, Princes Risborough (Tel. 3101 STD Code 0844 4), Aylesbury, Buckinghamshire. The Forestry Commission keeps in close touch with this work, some of which is done jointly by the two organisations.

 RESEARCH AND DEVELOPMENT DIVISION

Director	D. R. Johnston, M.A., F.I.For. (<i>Alice Holt</i>)
Director Designate	A. J. Grayson, M.A., M.Litt., M.I.For.
Administration and Finance Officer	J. E. Applegate (<i>Alice Holt</i>)

Chief Research Officer (South) D. A. Burdekin, B.A., Dip.Ag.Sci. (*Alice Holt*)

(With general responsibilities for research south of the Mersey/Humber line, and with specific responsibilities throughout Britain for research in arboriculture, seed, pathology, entomology, and wildlife, in silviculture and site studies in the lowlands, and for seed supply, engineering services and technical aspects of legislation relating to plant health).

Chief Research Officer (North) D. T. Seal, B.Sc., F.I.For.
(*Northern Research Station*)

(Head of the Northern Research Station with general responsibilities for research north of the Mersey/Humber line, and with specific responsibilities throughout Britain for research in silviculture and site studies in the uplands and for research in tree physiology and genetics).

STAFF AT ALICE HOLT LODGE

SILVICULTURE BRANCH (SOUTH)

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Transfers out: A. R. Brown (Forester) from Field Surveys, Ardentinnny, to West Scotland. P. A. V. Burke (Forester) Field Surveys, Dean, to South Wales Conservancy. J. Hunt (Head Forester) from Silviculture North, NRS, to South Wales Conservancy. M. J. R. Ingoldby (Forester) from Work Study, Alice Holt, to East England Conservancy. W. J. McCavish (Forest Officer I) from Silviculture South, Alice Holt, to East England Conservancy. A. T. Jones (District Officer I) from Work Study, Brecon, to South Scotland Conservancy. J. A. McIntyre (Forester) from Field Surveys, Inverness, to South West Scotland Conservancy. F. W. C. McLaughlan (HEO) from NRS to EMD, HQ. K. A. Russell (Head Forester) from Work Study, Mabie, to South Scotland Conservancy. A. A. Tait (Forester) from Field Surveys, Newton Stewart, to South Scotland Conservancy. S. C. Taylor (Forester) from Wildlife, Alice Holt, to South Scotland Conservancy. D. S. Whitaker (Forester) from Field Surveys, Dornoch, to North Scotland Conservancy.

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Deaths: G. R. Dunbar (Forester) Field Surveys, Perth.
K. W. Wilson (Forest Officer I) Publications, Alice Holt.

GLOSSARY

Latin names of trees cited by common name in this Report

Broadleaves

Alder, Common	<i>Alnus glutinosa</i>
Italian	<i>A. cordata</i>
Ash	<i>Fraxinus excelsior</i>
Beech	<i>Fagus sylvatica</i>
Birch	<i>Betula pendula</i> , <i>B. pubescens</i>
Hawthorn	<i>Crataegus monogyna</i>
Lime	<i>Tilia</i> spp.
Maple, Field	<i>Acer campestre</i>
Norway	<i>A. platanoides</i>
Red	<i>A. rubrum</i>
Oak, Pedunculate	<i>Quercus robur</i> (<i>Q. pedunculata</i>)
Red	<i>Q. borealis</i> (<i>Q. rubra</i>)
Sessile	<i>Q. petraea</i> (<i>Q. sessiliflora</i>)
Plane, London	<i>Platanus x hispanica</i>
Sycamore	<i>Acer pseudoplatanus</i>
Willow, Crack	<i>Salix fragilis</i>

Conifers

Cedar, Western Red	<i>Thuja plicata</i>
Cypress, Lawson	<i>Chamaecyparis lawsoniana</i>
Leyland	<i>x Cupressocyparis leylandii</i>
Fir, Douglas	<i>Pseudotsuga menziesii</i> (<i>P. taxifolia</i>)
Grand	<i>Abies grandis</i>
Hemlock, Western	<i>Tsuga heterophylla</i>
Larch, European	<i>Larix decidua</i> (<i>L. europaea</i>)
Hybrid	<i>L. x eurolepis</i>
Japanese	<i>L. kaempferi</i> (<i>L. leptolepis</i>)
Pine, Corsican	<i>Pinus nigra</i> var. <i>maritima</i>
Lodgepole	<i>P. contorta</i>
Scots	<i>P. sylvestris</i>
Spruce, Norway	<i>Picea abies</i>
Sitka	<i>P. sitchensis</i>

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